University of Alberta

Discrete Choice Analysis of the Feed Technology Decisions of Smallholder Dairy Farmers in Zimbabwe

By

Patience Sibongile Moyo ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements of the degree of Master of Science

in

Agricultural Economics

Department of Rural Economy

Edmonton, Alberta

Spring, 2001

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Degree: Master of Science

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ABSTRACT

This thesis investigates determinants of choices of supplemental livestock feed technology by smallholder Zimbabwe dairy farmers producing milk for sale. Survey data on observed choices of supplemental feeds included the introduced agroforestry technology of multi-purpose tree (MPT) fodder. A Random Utility Model to assess the determinants of these choices was postulated and tested. The main trade-off in farmers' choice of high protein feeds appeared between the use of purchased concentrates and MPT fodder; these feeds are mostly used in combination. The scale and productivity of the dairy enterprise, area planted to MPT fodder and experience with growing MPT fodder all significantly increase the probability of farmers' use of both MPT fodder and purchased concentrates. Model simulations show an increased probability of farmers' use of purchased concentrates with an increase in the number of cows producing milk for sale. Farmers' use of MPT fodder and purchased concentrates falls with increased crop revenue. Overall, profit motivation considerably influences use of purchased concentrates or on-farm produced MPT fodder and their substitution by smallholder Zimbabwe dairy farmers.

Acknowledgements

I am deeply indebted to my supervisors Dr. Michele Veeman and Dr. Wiktor Adamowicz for the valuable advice, guidance, encouragement and dedication. I would also like to thank Dr. Mick Price my defence committee member for the insightful comments and suggestions and the opportunity to reminisce on Zimbabwe. To Dr. M.L. Luckert, special thanks, for your guidance and commitment in Zimbabwe, for the thought provoking discussions regarding 'smallholder Zimbabwe', for encouraging me and for believing in me.

I extend my sincere gratitude to the sources of financial and institutional support that made this graduate experience and research study possible. These are Agroforestry Southern Africa (AFSA), the University of Alberta Fund for Student International Development Activities (FSIDA), the International Centre for Research in Agroforestry (ICRAF) Zimbabwe Office, the Institute of Environmental Studies, University of Zimbabwe and the Department of Rural Economy, University of Alberta.

The research study in Chikwaka Communal Area was facilitated by the untiring commitment of Innocent Nyamande, Proffessor Taona and Tichaona Takaidza who assisted me in the field and to whom I am greatly indebted. The participation and assistance of the members of the Chikwaka Dairy Association is gratefully acknowledged. I am also indebted to the ICRAF Harare office team leader, Dr. Ayuk, and staff Dr Lewis Hove, Mr. Dube and Dolphinia for their support.

To the University of Alberta Department of Rural economy as a whole, the wonderful opportunity you offered and shared with me in this invaluable experience that was my first two years of graduate school is greatly appreciated.

Finally, to my grandmother, parents, siblings and the extended family, thank you for the unconditional love, faith and support, oftentimes taken for granted.

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LIST OF ABBREVIATIONS

AGRITEX	Agricultural and Technical Extension Service
ARDA	Agricultural and Rural Development Authority
CSO	Central Statistical Office
DDP	Dairy Development Program
HPI	Heifer Project International
HYV	High Yielding Variety
ICRAF	International Centre for Research in Agroforestry
IIA	Independence of Irrelevant Alternatives
IID	Independently and Identically Distributed
LFA	Log Framework Analysis
MNL	Multinomial Logit
MPT	Multi-Purpose Tree
NR	Natural Region (Agro-ecological Region)
PRA	Participatory Rural Appraisal
PRM	Participatory Research Methods
RUM	Random Utility Model
TVC	Total Variable Cost

Chapter 1- - Introduction

This thesis focuses on the adoption and use of dairy cattle feed technology by smallholder farmers, with particular reference to the incorporation of agroforestry practices. The motivation for the study is the poor adoption rates of agroforestry practices, observed by agroforesters and researchers, which contradicts the widely held view that agroforestry technology offers a viable alternative solution to many land use problems. The problem to be evaluated is the assessment of the determinants of the adoption and use of an introduced agroforestry practice by smallholder dairy farmers.

A major problem in Zimbabwe's smallholder agricultural system is the inadequate availability and poor quality of livestock feed, especially during the seven to nine month dry season, and the high cost of purchased commercial feeds. An agroforestry technology, in the form of on-farm multi- purpose trees (MPT) which act in effect as fodder banks, has been introduced to smallholder dairy farmers in Chikwaka Communal Area as an alternative cash-saving source of high quality cattle feed. This thesis tries to achieve some understanding of the economic and socio-economic factors that may underlie adoption of this agroforestry technology that can be viewed as an alternative to the use of purchased commercial feeds. This study poses specific research questions and outlines hypotheses that focus on trying to understand the determinants of the adoption of this particular technology by farmers in the chosen study area.

Chapter 1 outlines the background to the research problem, the problem statement and the justification for the thesis research. This is followed by an outline of the specific objectives and the assumptions of the study. An overview of the research process and the organization of the thesis is also included.

1.1 Background

The smallholder farmer in Zimbabwe is characterized as operating within communal areas where there is no private ownership of land (Muir, 1994). The communal areas are mostly located in agro-ecologically marginal lands in areas of unreliable rainfall, often prone to dry spells. Almost 70 percent of Zimbabwe's population lives in communal areas and population density in these is estimated at about 29 persons per square km (CSO, 1986). The communal area population consists of smallholder farming households with average land holding per farming household of less than ten hectares. The rest of the land, in the form of range and woodland areas, is used communally for livestock grazing and collection of natural inputs and products. Most smallholders produce for subsistence, with some marketing of surplus production. There is more commercialization in the better agro-ecological regions, although total specialization in communal areas is unusual even where profitable cash crops are available (Muir, 1994). The smallholder sector has been disadvantaged historically in terms of land allocation, natural resource base and available technologies.

Smallholder farming systems are characterized by a variety of economic and biological interactions among crops, livestock, trees and people. Livestock play an integral role in cropping systems by providing animal draught power to augment manual labor in crop field preparation and production of manure for crop fields which helps increase soil fertility and thus sustain crop yields. Livestock act as a relatively liquid and high return and productive asset that contributes to risk spreading among farming activities and as a way of accumulating wealth (Guveya and Chikandi, 1996). Where livestock produces milk the smallholder household may also benefit from consumption and income generation. In addition, important social functions, such as bride price (*lobola*) and dead spirit appeasement (*ngozi*) payment, are fulfilled by livestock (Ndluli, 1999; Guveya and Chikandi, 1996). Woodlands and range areas provide important inputs and products such as fuel wood, medicine, construction timber, food, fodder and browse. There is also complementary use of other farmland outputs such as crop residues, weeds, graze and browse plants that provide feed for livestock, especially in the dry season when range land is less productive.

Agricultural productivity in Zimbabwe's communal area is constrained by a number of factors. These include inadequate water supply, declining soil fertility and soil erosion, limited capacity to purchase external inputs (Ehui and Swallow, 1994), and poor quality and insufficient livestock feed, especially during the seven to nine months of the annual dry season (Francis, 1993). Increased population pressure has precipitated land use problems such as increasing scarcity of natural resource products and encroachment onto marginal lands and communal areas by private individuals for settlement and to expand agriculture (Moyo, *et al.*, 1991). This suggests that, along with closer livestock-crop-tree-human interactions, exogenous inputs (such as new crop varieties, fertilizers, alternative fuel sources and improvements in animal nutrition) are needed to maintain and/or raise overall agricultural productivity (Ehui and Swallow, 1994). The green revolution technology of irrigation-based cropping with intensive inputs applied to hybrid seed that transformed much of Asia's production raised hope that hunger could be eliminated, and the carrying capacity of the land increased, through enhanced factors and the interaction of these on crop productivity. However, successful technology along these lines for the African agricultural setting is not yet available. Agroforestry, with the objective of optimizing ecological and economic benefits from tree-crop-animal-people interactions, potentially offers appropriate technologies for some land-use problems. This is the root of the growing interest in agroforestry as a viable solution to many challenges facing agricultural systems (Burch and Parker, 1991).

Agroforestry in its broadest sense is not a new concept but one that is practiced in most smallholder farming systems in Africa in one way or another (David, 1975; Cook and Grut, 1989; Campbell, Clarke and Gumbo, 1991). The primary objective for integrating trees into farming systems is for their productive and protective aspects in supporting agriculture, and hence for food production, rather than just for tree production (Steppler and Nair, 1987). Arguably, early applications of agroforestry involved few costs because of minimal resource constraints regarding land. It was not until the late 1970s that agroforestry was formally recognized and institutionalized as a sustainable land use system for marginal agricultural production systems. This transformed agroforestry from a passive traditional practice to an active and systematic land use system in farm management (Nair, 1991). More recently, efforts have been made to improve agroforestry systems and re-introduce the practice as an introduced technology developed through scientific research. Over the last two decades, scientific research has developed a wide range of agroforestry technologies to address problems of soil fertility, soil conservation, fuel wood and quality fodder production (Steppler and Nair, 1987). Modern agroforestry aims to develop technologies, with varying demands for land, labor, capital and other resources, that will fit into the current environment that has been altered by demographic, ecological, social and economic pressures.

Abundant reference has been made to the potential of agroforestry practices in alleviating the ecological and socio-economic problems of the rural poor. However, studies in India and in sub-Saharan Africa have rated the progress made in agroforestry adoption as low (Feder, Just and Zilberman, 1985; Alavalapati, 1995; Nair, 1991). The limits to widened adoption of agroforestry may be summarized as technical, perceptional, social and economic factors. Natural science research aims to reduce the technical limits to adoption of agroforestry technologies. However, there are still challenges that relate to the perceptional, social and economic factors of agroforestry affecting its adoption. This study investigates the impact of some of these.

1.2 The research problem and justification

The research problem of this thesis is to explore the reasons for the differential patterns of agroforestry adoption observed at farm levels in a specified region of Zimbabwe. Particular reference is made to the role of an introduced agroforestry technology in the livestock feed technology choices made by smallholder dairy farmers in Zimbabwe. Feed technology choices must be made by these farmers to alleviate the challenges they face in provision of adequate animal feed throughout the year.

The major, and thus most important source of livestock nutrition, for smallholder farmers in Zimbabwe is the fodder and browse from associated communal grazing and woodlands resources. Communal graze and browse availability has been reduced by the clearing of land for agriculture and the need for timber for construction and fuel (Clatsworthy, 1987). In addition to insufficient grazing land, a major constraint to animal productivity is the unavailability of feeds of high quality (feeds with sufficiently high crude protein content per unit of dry matter content) for livestock during the seven to nine months of dry season that is experienced annually. There are drastic changes in fodder and browse availability, both quantitatively and qualitatively, between the wet and dry season in Zimbabwe. The major dry season livestock feed is crop residues, but these are generally inadequate in quantity and while they provide carbohydrate, these are low in protein. Fodder production potentially alleviates feed availability problems and reduces cash expenditure on supplementary feeds. In general, however, fodder production in communal areas has been constrained by the availability of arable land and labor due to the competing need for food and cash crop production during the cropping season (Clatsworthy *et al.*, 1985).

The alternative source of quality feeds is purchased commercial supplements. These are unaffordable by the majority of smallholder farmers who face liquidity and credit constraints. Consequently, purchased commercial supplements are generally not used for maintaining beef and draught animals, but are used for dairy cattle feed supplementation where milk is marketed (Dzowela and Mafongoya, 1997). Since 1984, the Dairy Development Program (DDP) of the

Agricultural and Rural Development Authority (ARDA) has committed substantial resources to the development of a number of market oriented small-scale dairy schemes in Zimbabwe (ARDA, 1994). Dairy farming viability is, however, heavily affected by feed costs, labor costs, yield levels and problems of milk quality. Purchased and home produced feeds have been shown to account for approximately 70 percent of the total variable costs (TVC) of commercial dairy farming in Zimbabwe while labor accounts for 11 percent of the TVC (Dube, 1995). Reliance on purchased feeds has been observed to contribute to financial losses by smallholder dairy enterprises, as feed costs are high relative to returns (Mupeta, 1995).

Livestock feed availability and the accessibility of its use is thus central to the viability of small scale dairy schemes in Zimbabwe. With this in mind, the International Center for Research in Agroforestry (ICRAF) in Zimbabwe, has concentrated efforts on introduction of on-farm multi-purpose tree (MPT) fodder bank technology developed on research stations. The MPT fodder trees have been introduced to dairy farmers in Chikwaka communal area as a cash-saving alternative source of high quality feed for livestock feed supplementation since 1994 (Dzowela and Mafongoya, 1997). However, differential patterns of agroforestry adoption are observed at the farm level. In this study, potential explanators of the differential adoption and patterns of use of MPT fodder as an agroforestry technology will be investigated by examining the feed technology choices made by dairy farmers in Chikwaka communal area. The study was applied in the 1998/99 agricultural year. It is hypothesized that the decision to integrate MPT fodder in the dairy feed technology bundle may be determined by several factors. These are components of the dairy management system such as available resources, alternative feeds and their resource demands; seasonal factors; economic incentives; and individual characteristics of the farming households. The following sections of this thesis outline and apply the framework chosen for investigating the *ex post* adoption and use of MPT fodder as an introduced agroforestry technology, in the context of multiple dairy feed technology alternatives.

1.3 Assumptions of the research study

The main assumptions underlying this analysis are that:

1. The innovation to be assessed, defined as 'a new idea, product or process', is on-farm agroforestry multi-purpose trees (MPT) used as a fodder bank. This technology was introduced to the study area by ICRAF in 1994 and all farmers in the survey sample have

been exposed to information about it.

2. An innovation-decision process, as defined by Rogers and Shoemaker (1971), is the "mental process through which an individual passes from first knowledge of an innovation to a decision (action) to adopt or reject, and to later confirmation of this decision". Adoption is considered a yes or no event, rather than exhibiting degrees of adoption, and defined as the "decision to make full use of an innovation" (Knudson, 1988). According to this characterization of the innovation-decision process by Rogers and Shoemaker (1971), individual farmers at this point in time can be viewed to be at the confirmation phase regarding adoption of on-farm MPT fodder bank technology;
3. The nature of technology adoption in this study is taken to mean the decision to use a feed technology bundle integrating MPT fodder. The observed pattern of MPT fodder use by farmers in the 1998/99 agricultural year is used here as a proxy measure of the cross-sectional adoption, at this point in time, following introduction of the technology by ICRAF in 1994. This study varies therefore from the approach of that applies aggregate adoption models to track adoption patterns by farmers over time, such as the seminal study by Griliches (1957).
4. Use of MPT fodder trees is not considered in isolation but is viewed as a component of the total feed strategy followed by individual farmers. This may involve farmers' use of any combination of six identified main feed sources, namely communal grazing, crop residues, purchased concentrates, pasture grasses and legumes, MPT fodder and maize. The particular feed technology bundle that is chosen can be a composite of any or all the six identified feed sources. This will include MPT fodder for the households that adopt this agroforestry practice.

1.4 Research objectives

The primary objective is to explore the reasons for the differential patterns of *ex post* adoption and use of an introduced agroforestry technology observed at the farm level. A model of choice among the feed technology alternatives is formulated and tested using econometric techniques on data collected through farmer interviews.

The specific objectives of this study are to:

1. Define the livestock feed technology alternatives available to farmers according to the

observed combinations of the six identified main feed sources (communal grazing, crop residues, purchased concentrates, pasture grasses and legumes, MPT fodder, maize). Then group the sample of farmers by observed feed technology choice and describe group differences according to economic and socio-economic variables;

2. Frame testable hypotheses to test the relative importance of identified explanators of feed technology choice, for both wet and dry seasons. The hypothesized explantors include factors related to the dairy management system such as available resources, alternative feeds and their resource demands; seasonal factors; economic incentives; and individual characteristics of the farming households.
3. Model the multiple feed technology adoption decision to investigate the interdependent adoption decisions and significant explanatory variables. Evaluate probabilities of choice for each feed technology alternative and then simulate choice probabilities for changes in key significant explanatory variables;
4. Assess the implications of the findings of the analysis outlined above for the potential adoption and use of agroforestry technology designed market oriented smallholder dairy feed systems in Zimbabwe

The results of the analysis may also shed light on implications for agroforestry practice, policy, research and extension that is related to on-farm multi-purpose tree fodder technology targeted for smallholder dairy farmers.

1.5 The research process

The study was accomplished in four stages. The first stage involved extensive literature review and consultation with academic advisors. The main outputs included formulation of the research questions and the definition of the conceptual and empirical models to address these questions by identifying the background issues surrounding the problem through the review of current research in the area. Since data were to be sought directly from individuals, the research proposal was submitted to the Faculty Ethics Review Committee for assessment and approval. The second stage of the research process involved informal field surveys in Chikwaka communal area and consultations with key informants, particularly ICRAF personnel and farmers, on the key elements of the problem in order to facilitate questionnaire development. The third research stage involved pre-testing and formal administration of the survey questionnaire to members of the Chikwaka smallholder dairy scheme. Subsequently data entry and analysis was pursued to obtain quantitative results for the postulated models to meet the objectives of the study. The fifth and final stage of the thesis research involved report writing and presentation of findings.

1.6 Thesis organization

Following this introductory chapter, in Chapter Two a brief review of literature related to the research questions is given. The review covers theoretical concepts and previous analyses that focus on technology adoption. This review also focuses on evaluation of empirical methodologies in studies of adoption, including the adoption of agroforestry technology. Chapter 3 presents an overview of the study area and outlines the survey research methods, the sample selection and the questionnaire. The current state of dairy cattle feed practices focusing on the main feed sources that are used and definition of the feed technology alternatives is outlined. This is followed by a description of the sample, in terms of economic and socio-economic features of households and feed technology choices. Chapter 4 discusses the conceptual and empirical framework that shapes the analysis. Sections are included on elements of decision theory and the economic theory of household choice in the context of the household production-consumption model. Brief overviews of discrete choice theory, random utility theory and multinomial choice models are also given. In Chapter Five, a formal presentation of variables and models postulated is given, as is discussion of *a priori* expectations and presentation and discussion of the estimation and simulation results. The final chapter provides a summary of the thesis study and results, draws conclusions, highlights policy implications and notes limitations of the study and areas for further study.

Chapter 2 - - Literature Review

This chapter reviews literature relevant to the study by examining previous and current work on theoretical concepts, empirical methodologies and results of analyses of technology adoption and diffusion, including a brief section specifically on the adoption of agroforestry technology.

2.1 Historical overview of technology adoption and diffusion

Given that society cannot benefit from investment in technology research unless the outputs are relevant to and adopted by farmers, one major focus of the subject areas of rural sociology and agricultural economics literature is the way in which farmers adopt technology.

Feder, Just and Zilberman (1985) suggest that there is an important distinction between individual and aggregate adoption. The individual adoption process consists of knowledge, persuasion, decision (or action) and confirmation (Blackburn, 1984). Aggregate adoption is concerned with an entire group of potential adopters, rather than with individual decisions. Aggregate adoption is a macro level concept and deals with rates, trends and patterns of use of a specific innovation by the target group or within a certain geographic area.

Rural sociologists (Beal and Bohlen, 1957) performed much seminal work on technology adoption that has been the basis for further analysis of economic issues (Peterson and Hayami, 1977). Sociologists have concentrated on the diffusion patterns of innovations as these progress through time and space, as well as on the characteristics of individual adopters and the nature of interpersonal relationships involved in adoption. Sociologists have placed emphasis on understanding how the different socio-cultural characteristics of adopters are exhibited in a spectrum ranging from innovators to laggards and the resulting tendency for an S-shaped diffusion curve. This type of approach attempts to provide a better understanding as to which farmers might adopt a new technology and which ones might be late adopters. These studies often aim to provide information on how such characteristics determine the most effective means of communication for accelerating the diffusion process (Peterson and Hayami, 1977).

Economists, on the other hand, have focussed on how economic variables, such as the profitability of innovation and the asset position of the firm, influence the rate of technology diffusion (Griliches, 1957; Mansfield, 1963). An agricultural economist pioneer in this field, Griliches (1957), summarizes the diffusion path of hybrid corn by fitting a logistic trend function to data on the percentage of corn area planted with hybrid corn in the various states of the USA. The logistic function is described by three parameters. These are: an origin indicating the date at which 10 percent of its ceiling corn acreage was planted to hybrid seed; the slope, measuring the rate of acceptance; and the ceiling, measuring the level of acceptance at which use of hybrid seed tended to stabilize. Griliches (1957) attempts to measure changes in the demand for hybrid seed by observing the differences in the origin, slope and ceiling of the logistic function and seeking explanators of these differences. Results indicate that differences among regions in the rate (slope) and level (ceiling) of acceptance are both functions of profitability of a shift from open-pollinated to hybrid corn. Griliches (1957) also finds that the motivation for developing technology by private companies is provided by the potential profits from production and sale of hybrid seed. Other studies of adoption, for example by Martinez (1972) on adoption of hybrid corn in Argentina, and Maier (1969) on adoption of the mechanical cotton picker in the USA, also reveal that technology acceptance was closely related to profitability. The economic approach to the study of the diffusion of new techniques was further developed and applied to analyze industrial innovations by Mansfield (1961, 1963).

Traditionally, most of the diffusion models developed and tested by economists were designed to describe or analyze diffusion among farms within a particular area over time in response to profitability of technological change. These studies take the attributes of technology and of potential adopters as given (Peterson and Hayami, 1977). Some analyses by economists have been criticized by sociologists who cite familiarity or congruence with a technique or input (Brander and Strauss, 1959) and communication and interaction between people (Havens and Rogers, 1961), as the important factors. Griliches (1960) points out that the "profitability" approach can be broadened by allowing for differences in information, risk preference, and so on, bringing it as close to the "sociological" approach as one would want. Indeed, later analyses by Nelson and Phelps (1966), Welch (1970), Kislev and Schchor-Bachrach (1973), Huffman (1974) and others attempt to broaden the assessment of the influence of profitability to include education and human capital measures of potential adopters. More recent studies on technology adoption, at the farm level, integrate economic variables (for example, profitability, costs, scale, productivity and resource endowments) and the characteristics of potential adopters (such as age, education, experience, industry involvement and off-farm labor supply), see Zepeda, 1990; Zepeda, 1994; Dorfman, 1996; El-Osta and Morehart, 1999.

Many theories and models have been postulated and tested on hypotheses about adoption of technology. Many studies of adoption have concentrated on either predicting the qualitative effects of variables on technology adoption or on identifying factors correlated with adoption decisions. The following discussion considers some theoretical models, concepts and empirical approaches to explain technology adoption that may be relevant to this study.

2.2 Theoretical concepts in technology adoption

2.2.1 Socio-economic and socio-cultural factors in technology adoption

Rogers and Shoemaker (1971) define an innovation as "an idea, practice or object perceived as new by an individual", and diffusion as "the process, by which new ideas are communicated to the members of a given social system". These authors also conceptualized "innovation-decision" as the "mental process through which an individual passes from first knowledge of an innovation to a decision to adopt or reject, and to later confirmation of this decision." The process of adoption and diffusion was broken down in terms of adopter categories: innovators, early adopters, early majority, late majority and laggards by Rogers (1983). Much extension work for the transfer of new technology in the developing world has been based on the above sociological concepts and the concept of "opinion leaders", individuals that informally influence other individuals' attitudes or behavior in a desired way.

Sociologists (Rogers and Stanfield, 1968; Rogers and Shoemaker 1971) have found that the adoption of new technology is positively influenced by the current level of productivity, and that innovation is associated with farm size as well as farmer experience, education, and industry involvement. These are economic variables and measures of human capital from an economist's viewpoint since productivity reflects the farmer's management ability, and education and experience contribute to human capital formation. Feder, Just and Zilberman (1985) surveyed economic studies of technology adoption and found that farm size, risk and uncertainty, human capital, labor availability, credit, land tenure, and complementary input availability were major factors in the adoption of agricultural technologies in developing countries. Sociological studies indicate other variables, that reflect knowledge, perception or personality, may be relevant such as farmer perceptions of the benefits of the new technology, limited knowledge of modern inputs and their effects, risk attitudes and learning (Hiebert, 1974). In addition, favorable attitude to change, high aspirations (possibly for improved welfare or profit), empathy, and ability to deal with abstractions and dogmatism are held to influence the adoption and diffusion of modern technology (Rogers and Shoemaker, 1971; Lipton and Longhurst, 1986; Reardon and Vosti, 1992). Major characteristics of individuals that influence adoption can therefore be categorized as socio-economic status, personality variables and communication factors (Rogers and Shoemaker, 1971).

Perceptions may be concerned with the extent to which farmers actually discern a problem that may be addressed through technology adoption. Objectives, as they are influenced by preferences and perceptions, shape what, if any, technologies are considered for adoption. Whether to adopt a particular technology must be considered in the context of existing technology and any other potential new technologies. Farmers' perceptions of the benefits of new technology relative to current practice are important. Roger and Shoemaker (1971) show that the attributes of the innovation are important factors in explaining the adoption process. These attributes include the innovation's relative advantage, complexity, compatibility with existing systems, its being amenable to trials and ability to observe results from the trials. Complexity increases the learning costs for farmers while the ability to observe results may reduce objective risks associated with adoption. Amenability to trials is tied to divisibility of the technology since if a technology is divisible, the farmer can experiment and adopt in incremental steps thus reducing both the risk and level of economic investment that is needed. Certain scales of implementation may transcend farm boundaries and require collective action, complicating the adoption process. This may occur for example, with soil conservation technologies on slopes.

Social differentiation by gender is an important consideration in decision making in rural households, in which gender, historically has played a functional role, based on division of labor between men and women for various production and consumption activities (Muchena, 1994). An understanding of such differentiation in roles, and in access to and control of resources, may improve understanding of the potential impacts of technology adoption on the rural household and community. Some studies indicate that where technology is appropriate for the tasks they perform, women readily adopt (Mehra, 1994). If technological innovations displace women from traditional occupations, they are often less well equipped in terms of education and skills to find alternative employment due to the numerous social and institutional constraints they face in participation in food and cash crops, extension and other non-agricultural activities (Mehra, 1994).

2.2.2 Economic factors and incentives in technology adoption decisions

According to Feder, Just and Zilberman (1985), an analysis of individual adoption should involve a model of the individual's decision making process. The way in which an individual combines inputs to produce outputs or utility may be described in economic terms through a production function. A generalized production function may be written as $Y = f(x)$, where Y represents the quantity of output or utility and x is the quantity of input. The traditional objective of the rational firm, or economic agent, would be to maximize profit or utility by deciding the level of output Y to produce. Profits are defined as total revenue net of the total costs of the inputs x. With profitability as the main attribute of concern, where adopting an innovation is more profitable than the current situation, an individual is expected to adopt.

In support of the traditional objective of the rational firm, Darling (1990), in a study on adoption of canola in Western Canada, concludes that 'adoption is driven ultimately by the aggregate effect of the micro-economic analyses done by the individual farm mangers when they make their cropping decisions. These analyses may be formal or informal but the end result is the tendency for farmers to maximize the potential profitability of their farming operations.'

The following discussion reviews concepts, approaches and factors postulated by economists to explain processes that influence development and adoption of new technologies.

2.2.2.1 Induced innovation and the technological treadmill

The concept of induced innovation, as first introduced by Hicks (1932), attempts to explain why technical change moves in the direction it does at the aggregate level. The induced innovation hypothesis, as later developed by Hyami and Ruttan (1971) to account for public sector investment in agricultural technology research, states that:

> Farmers are induced by shifts in relative prices, to search for technical alternatives which save the increasingly scarce factors of production. They press public research institutions to develop new technology, and also demand that agricultural supply firms supply modern technical inputs which substitute for more scarce factors. Perceptive scientists and science administrators respond by making available new technical possibilities and new inputs that enable farmers to profitably substitute the increasingly abundant factors for the increasingly scarce factors, thereby guiding the demand of farmers for unit cost reduction, in a socially optimum direction.

Hyami and Ruttan (1971) also suggest that "technical change is guided along an efficient path by price signals in the market" where markets are operating efficiently and where there is "effective interaction among farmers, public research institutions and private agricultural supply firms". The response of research scientists and administrators thus represents a critical link in the inducement mechanism (Peterson and Hayami, 1977).

A rather different concept is that of the "technological treadmill", developed by Davis (1979) which looks at how technological change has affected the structure of farming. This model describes the reduction in gains from adoption that is associated with limited demand for output, as occurs with a price inelastic demand as applied for domestic demand for agricultural commodities. Early adopters benefit from a cost-reducing technology whilst late adopters are pressured by price-cost influences to adopt. Increased output stimulated by adoption can thus lead to large price changes that may substantially reduce the benefits to adoption for the late adopters. When technology is scale-related, this influence and the price-cost trends noted above, affect the structure of the farming sector. For individual farmers and agricultural supply firms the maximization of future profits can be assumed as a major determinant of the direction of technological change. This observation is supported by findings of Griliches' (1957) study of hybrid corn adoption by US farmers. In this study, agricultural supply firms and public research institutes acted rationally by developing hybrid varieties for the corn-belt areas long before developing hybrids for the lower potential supply regions. Similarly farmers in high output regions planted greater proportions of their total corn acreage to hybrid varieties earlier because of their profit potential.

2.2.2.2 Portfolio selection, risk and human capital theory

The availability of any new production technology presents the farmer with a type of portfolio selection problem, *vis-a-viz* the use of old and new technologies. The portfolio selection problem can be viewed as the choice of an optimal mixture of activities that may differ in both riskiness and expected returns. Unlike the simple portfolio selection problem, the farmer may have some degree of control on both the level of risk and the mean return. For example, this can apply through farmers' use of inputs such as fertilizers and pesticides, as well as through seeking information.

Schultz (1975) suggests that any new technology may cause disequilibrium in the farming system, at least in the short term, due to information constraints. These constraints may be alleviated through search and experimentation which enables a farmer to move towards equilibrium with efficient resource use once again (Schultz, 1975). A study by Hiebert (1974), of HYV rice adoption in the Philippines, concludes that as the farmer's information and understanding increases, uncertainty decreases and the producer is able to adjust input decisions so that the probability of a higher payoff from the new technology is increased. Assuming that the innovation is superior to the old technology, farmers will tend to allocate more and more of their land to the superior new technology, as was the case for HYV rice where complementary inputs of irrigation, fertilizers and pesticides were available in the Philippines. A similar study of rice farmers in the Philippines indicates that intensive extension contact, as a source of information, is manifested in a consistently higher level of expertise of farmers with contact compared to others (Feder and Slade, 1984).

Risk perceptions may also be influenced by human capital, measured by education and experience (Zepeda, 1994). Education represents a decision maker's ability to assess risk. Provided an innovation is profitable, the accumulation of favorable experiences will eventually induce most farmers to adopt the new technology. The process of education can be viewed as an act of investment in people making educated people bearers of human capital (Nelson and Phelps, 1966). Education has been hypothesized to facilitate diffusion of new technology because education enhances one's ability to receive, decode and understand information, all of which are important first steps in performing or learning to perform many tasks (Nelson and Phelps, 1966; Schultz, 1971; Feder, Just and Zilberman, 1985). Better educated farmers may be quick to adopt profitable new processes and products since the expected payoff from innovation may be greater and the risk may be smaller than for less educated farmers. This occurs if farmers are better able to discriminate among promising ideas and less likely to make mistakes. Some farmers may find it prudent to delay the introduction of a new technique until they have concrete evidence of its profitability, for example, after knowing that their more educated friends have adopted the technique successfully.

The existence of a linkage between adoption and education has been investigated by many scholars including Feder *et al* (1985). Theory and evidence generally indicate a positive relationship, suggesting that education may be an important factor encouraging adoption. In a recent study, Yifu Lin (1991) investigates the role of education in farm household decisions regarding adoption of F1 hybrid rice seed in China. Adoption of the new technology is treated as a portfolio selection problem with the new agricultural technology reflecting high yield, low cost and other desirable traits, highlighting the importance of economic considerations to adoption decisions. Lin (1991) notes that the changes in the production process involved in the adoption of a new technology may bring risks resulting from imperfect information and the possibility of committing errors.

2.2.2.3 The threshold model and scale/size effects

Davies (1979) applied a threshold model to analyze adoption. The threshold model represents an equilibrium condition derived from the rational choices of individual economic agents. It was concluded that adopters and non-adopters from a heterogeneous population could be separated by a critical threshold level of the heterogeneous characteristic. The source of heterogeneity could be associated with the farmer, for example, from experience, or with the farm, for example from farm size. The critical level itself is viewed to be determined by prices and costs and thus to change with these underlying economic variables. If there are few potential adopters with a particular characteristic near the threshold value, for example farm size, the effect of a price change on output supply and input demand would be considerably smaller than if many individuals shared that characteristic.

Farm size reflects the scale effects of fixed technologies, technologies that are complements to fixed technologies, or technologies that require fixed quantities of physical or human capital. Farm size may be a proxy for access to credit and other inputs, and access to information or human capital. Farm size can be expected to relate to the ability to bear risks and larger farmers are likely to allocate more resources to the acquisition of information (Zepeda, 1994). Lindner (1979) points out that larger farms have more to gain from on-farm experimentation and so tend to have shorter lags in evaluation during the adoption process. Feder *et al* (1985) discuss farm size as it relates to technology adoption and conclude that many other composite factors come into play. For example, these could include the fixed adoption costs for technology that is not scale-neutral, which may allow large farms to adopt earlier due to high establishment costs and the need for credit to which larger farms have better access (Greene, 1973).

2.2.2.4 Complementary inputs, innovations and institutions

The feasibility of technological options typically depends on the environment that is required to support particular technological innovations in terms of availability of inputs and institutions. The nature of existing production technology influences the adoption of new technology because of compatibility or otherwise with the new systems. Complementarity of new technology with the current system may be undermined by competing demands for complementary investments such as land, labor and capital (Erenstein, 1999). Thus, the timing of costs and benefits can become a critical attribute in adoption of new technologies. Labor, credit, land, raw materials, land tenure and marketing institutions, technical and extension support are all potential complements to technology adoption; if they are limiting, they will act as limiting constraints to adoption of a new technology (Zepeda, 1994).

Feder, Just and Zilberman (1981) discuss conflicting theoretical and empirical findings about the effect of land tenure on technology adoption. Evidence from studies of the adoption of Green Revolution technology in India indicates that tenant farmers tended to lag behind in the early years. However, Schutjer and Van der Veen (1977) suggest that any observed tenancy effect may have been indirectly due to access to credit, input markets, product markets and technical information. Feder *et al* (1981) suggest that access to the marketing network and linkages to the transportation system are critical for adoption, particularly in the case of highly perishable goods for which guaranteed marketing outlets may be essential. Similarly, complementary innovations may need to be introduced simultaneously to realize the potential full benefits of a given technology. This has been seen, for example, where HYV seed and fertilizers or pesticides were required as a technology bundle, which highlights the importance of supply side and marketing requirements (Feder *et al*, 1981).

Farmers operate under resource constraints with, for example, limited supplies of cash, water, fertile land, livestock feed resources and labor in peak periods. Technology adoption requires use of resources directly, in terms of investment and maintenance requirements (cash or credit to purchase fertilizers, and labor to work fields). Resources may also be required indirectly as in the case of agroforestry, in terms of foregone production (such as land for cash crops). Labor is a very significant input in the agricultural systems of developing countries. Markets for rural labor are frequently not well developed and wages are low. However, the opportunity costs of labor use, as in the profit from alternative uses of labor (such as formal wage employment or cash crop production) foregone by engaging labor in a given activity, will affect decisions concerning labor use. Opportunity costs of labor vary across farming households, seasons and activities. The demand for labor is high during peak periods that require agricultural on-farm work for land preparation, planting, weeding and harvesting. The opportunity cost of labor in other activities may be high during these times, relative to the slacker agricultural period, when increased off-farm activity is often observed.

Labor can be a critical binding constraint that requires adequate consideration in technology transfer. Hicks and Johnson (1974) found that higher rural labor supply led to greater adoption of labor-intensive rice varieties in Taiwan. Norman (1969) concluded that an operative constraint in African farming systems is the peak-season labor scarcity. The evolution of labor markets may result if an innovation creates effective demand for labor, inducing changes in the income-leisure equilibrium (Feder *et al*, 1981). The intensification of agriculture in southern Israel, producing an incentive for the nomadic Bedouins to become hired farmhands, is cited as an example of this by Feder *et al* (1981).

Developing country farm households typically face binding liquidity and credit constraints implying a correspondingly high opportunity cost of capital (Erenstein, 1999). There are few rural financial institutions that offer formal credit and informal sources charge high interest rates (Lele, 1975). The need to undertake fixed investments may prevent small farmers from adopting new technology quickly due to dependence on credit availability (Feder *et al,* 1981). Lipton (1979) cites differential access to capital as a factor in differential adoption rates, particularly for lumpy or indivisible technology like tractors. On the other hand, Schutjer and Van der Veen (1977) cite the conclusions of many authors that lack of credit is not crucial to adoption of scale neutral technology such as fertilizers and HYV seed. For scale-neutral and capital-intensive technology, liquidity is expected to be a more significant factor. Opportunities for off-farm income generation, and the availability of transfers from family members in wage earning employment, may alleviate liquidity and credit constraints that farmers may face in financing new technology.

2.3 Agroforestry technology adoption and the farming system

Resource allocation decisions in smalloholder farming households reflect objectives as shaped by preferences and perceptions related to profit, welfare and time preferences in timing of consumption. Households decide to engage in alternative productive activities such as agriculture, agroforestry, off-farm work or other activities that must compete for a limited stock of resources and the institutional environment. In an article on social and economic challenges in the development of complex farming systems, Pannell (1999) concludes that the biggest challenge in developing a new farming system is to have it adopted and maintained by farmers (Pannell, 1999). The difficulty is increased if the new farming system is complex and/or radically different to current farming practice, as is commonly found with introduced agroforestry technology. In such cases supply side interventions in the form of complementary investments by external agents in infrastructure and inputs for establishment of seedling nurseries, training, trial plots, demonstrations and extension, may be required to off-set initial costs and risks, thus motivating agroforestry adoption.

2.4 Evaluating empirical analyses of technology adoption

2.4.1 Methodological shortcomings

Much empirical work has lacked a theoretical basis on which to specify structural relationships and interdependencies among variables explaining adoption. As a result, models specified may not correspond to any underlying decision behavior. In addition, models have often failed to meet the statistical assumptions that are necessary to carry out hypothesis tests upon which conclusions are based (Feder *et al,* 1981).

Many studies try to determine the directional impacts of certain explanatory variables rather than their quantitative importance. For example, numbers of studies have applied non-parametric hypothesis tests of postulated explanatory variables based on chi-square contingency tables and simple factor correlation analysis, which do not give insights on quantitative importance of individual variables. Quantitative studies of adoption, using econometric techniques, have tended to concentrate on simple regression, explaining the decision to adopt versus non adoption rather than the extent of adoption (Feder *et al*, 1985). However, a full understanding of technology adoption cannot simply be categorized as adoption or non-adoption since adoption takes place by degrees. For example, knowledge that a farmer is using HYV seed may not provide much information about farmer behavior in that he may be using the hybrid seed on one percent or 100 percent of his acreage. On the basis of a comprehensive review of literature, Schuter and Van der Veen (1977) conclude that, "the major technology issues relate to the extent and intensity of use at the individual farm level rather than to the initial decision to adopt the new practice". In this context, adoption cannot be represented adequately by a dichotomous qualitative variable, as has often been the case. A more appropriate reflection of the adoption rate may be given by a limited continuous variable, such as acreage for HYV planting, with the value of zero applying for non-adopters (Feder *et al*, 1981).

Numbers of studies have focused mainly on adoption of a single technology or on a bundle of technologies that are considered as a single unit. Feder *et al*, (1981) cite David (1975) as explaining the quantity of fertilizer used by ordinary regression on the use of HYV seed, among other variables. However, the decision to use HYV and fertilizer are normally simultaneous decisions, resulting in biased and inconsistent results. It is evident that many technology adoption decisions are simultaneous. Indeed, Nerlove and Press (1978) gave a pioneering discussion of the logit model to analyze several adoption decisions in a truly simultaneous equation framework. Interactions revealed by such simultaneous modeling methods may be useful for policy related to technology adoption. For example, Feder *et al.* 91985) maintained that where several technologies are considered at once, such as hybrid seed and chemical fertilizers, it may be observed that farmers are more likely to adopt fertilizers if hybrid seed is adopted first and not vice versa. This and similar results suggest pointing extension efforts toward recognizing complementary technologies when dealing with transfer of new technology.

Similarly, in some studies of adoption, other endogenous variables have been used as explanatory variables without regard for the simultaneous equation bias that can result. One example has been argued by Zepeda (1994), noting that economic theory suggests that technology affects productivity and that the two can be viewed as being jointly determined. Therefore estimating an *ex post* technology adoption model with productivity as an explanatory variable can be subject to simultaneous equation bias (Zepeda, 1994). In an attempt to account for this simultaneity, Zepeda (1994), models productivity and technology adoption decisions as a system of equations. Her results illustrate joint dependence of these as endogenous variables, highlighting the importance of adequate consideration of simultaneity in modeling adoption decisions.

2.4.2 The contextual relevance of this study to previous research

An adoption model that concentrates on adoption of single technologies without consideration of the alternatives that may be complements, substitutes or supplements may mask the realities faced by households in their particular technological and socio-economic environment. Some recent quantitative studies of technology adoption decisions consider a set of technologies from which one potential bundle, of many combinations of technologies, can be chosen by a producer. Farmers are assumed to consider a set of possible technologies or technology bundles and to choose that particular technology or bundle that maximizes expected utility or profit, conditional on the adoption decision. Rauniyar and Goode (1992) were pioneers in examining the adoption of seven different technologies by maize farmers in Swaziland. Using factor analysis, they found that the seven technologies could be grouped into three interrelated sets of technologies that appeared to have common factors influencing their adoption. This study pointed to the importance of a multivariate approach to adoption studies.

It has been argued that the adoption decision should be modeled in a multivariate context to capture economic information contained in interdependent and simultaneous adoption decisions (Dorfman, 1996). Caswell and Zilberman (1985) pursued a multivariate approach to analysis of adoption by examining the adoption of two improved irrigation methods (drip and sprinkler) relative to the use of traditional furrow irrigation. They employed a multinomial logit model measuring the probability of adoption of each improved irrigation method relative to the traditional one.

This thesis follows a similar approach to Caswell and Zilberman (1985). It considers adoption of dairy feed technology in a system in which there are discrete alternative technology bundles. Farmers may or may not incorporate an agroforestry technique as a component of the joint technology adoption decision. The multinomial logit model specification is used to model choice. This model enables estimation of probabilities of choosing among the feed technology alternatives that incorporate combinations of a number of feed sources.

Chapter 3 - - Study Area, Survey Methods and Data

The first section of Chapter Three describes the study area in terms of selection criteria, geography, institutions, and features of the local economy. The next section outlines the survey methods, provides a description of the sample and the survey instrument and gives an overview of the current state of dairy feed practice. This is followed by discussion of the process by which farmers were grouped by feed technology choices according to observed data. The chapter concludes with a description of the sample according to feed technology choice by presentation of statistics for key variables.

3.1 The Study Area

3.1.1 Study area selection criteria

The main criterion used in selecting the postulated study area was the presence of an established ICRAF on-farm agroforestry research project. The presence of the Dairy Development Project (DDP), maintained under the auspices of the Agricultural and Rural Development Authority (ARDA), was an entry point for ICRAF to interact with smallholder dairy farmers in the Chikwaka area. In 1994 ICRAF introduced MPT on-farm fodder banks for livestock feed supplementation to the members of the Chikwaka Dairy Association. Since then, numbers of farmers have begun to grow these fodder trees and use them to supplement dairy cattle feed throughout the year. Chikwaka communal area was chosen for this study due to the high frequency of MPT on-farm fodder banks on individual farms. Another factor was the proximity of this area to Harare, where administrative support for the project was centered. This resulted in reduced communication, transaction and transportation costs, in the context of limited research budget.

A disadvantage of the Chikwaka Communal Area as a research site is the high frequency of contact that households have with researchers and external development agents due to its proximity to Harare. Much of this direct interaction with farmers is, however, limited to the Gutu ward area that is nearest to the Juru growth point. This area has been classified as over-surveyed, due to roadside bias (Chambers, 1989). The current research study, however, targeted all farmers that are members of the Chikwaka dairy association including those at the farthest end of Mwanza ward, which is as far as 25 kilometers from the growth point. Discussions with farmers and key informants from Mwanza and Dzvete wards confirmed that they had had little direct contact with researchers and change agents unless they traveled as far as the Juru growth point to participate in development activity. Most farmers from Gutu ward were in the pilot sample (pre-test group) whilst Mwanza ward farmers constituted 78 percent of the final sample of 118 household surveys used in this analysis.

3.1.2 Geography

The Chikwaka communal area is located in Mashonaland Central Province, 50 kilometers north of the capital city, Harare. The area falls within Agro-ecological Region II, an intensive farming region. Average annual rainfall ranges from 800 to 1000 mm which is generally regarded to be a good level of precipitation but the area is also prone to dry spells as occurred between 1986 and 1991. The rainy season falls between October/November and March/April each year with the remaining seven to eight months being dry. Mean annual temperatures reach a low of five degrees centigrade during the cool season and a high of 35 degrees celcius in the hot season around October. Chikwaka experiences ground frost each year between June and July. Chikwaka soils are sandy and of poor fertility. The area has an undulating topography with granite rocks dotted in the landscape (Burgers, Dzowela and Franzel, 1997).

3.1.3 Demography

The total land area of the Chikwaka communal area is 3 290 square kilometers. The population density is 33 persons per square kilometer which is higher than the country average of 29 persons per square kilometer for communal areas in Natural Region II (CSO, 1992). That there is severe population pressure in this area is evidenced by the near absence of any natural woodland areas and the small size of individual landholdings of 4.6 hectares per household. Average household size in this area is 5.5 people. The resident adult population is relatively low due to urban migration of adults that leave the risks of farming on limited land and aim to diversify household income by seeking off-farm employment in Harare. Up to 32 percent of households have been found to hire labor to augment on-farm family labor (Burgers, Dzowela and Franzel, 1997).

3.1.4 Land holdings and land use pattern

The smallholder farmers in the Chikwaka area typically are mixed farmers. Cropping programs include the staple maize predominantly, integrated with cash crops such as cotton, sunflower, groundnuts and tobacco. Vegetable gardening is also practiced during the off-season months between May and November. Many households own cattle, goats and poultry. Households in villages are spatially organized in rows with each household having a yard at the homestead. Households are also allocated fields and gardens near the yard or further afield. Indigenous cattle (non-dairy cattle) are grazed collectively away from cropping fields in communal grazing areas. There are not many grazing areas, so herders tend to weave around crop fields and makeshift roads. About seven percent of Chikwaka communal area farmers own dairy cattle (Franzel, 1999). These are mostly cross-breed and/or exotic dairy cattle. The dairy herd is normally kept away from the rest of the herd to avoid contamination with pests and disease. The dairy farmers that are members of the Chikwaka Dairy Association market some of their milk through the center that is located at Juru Growth Point whilst the rest is side-marketed to neighbors and/or retained for home consumption.

3.1.5 Institutions

Chikwaka communal area falls in the Goromonzi District and is comprised of 3 administrative wards namely, Gutu, Dzvete and Mwanza. The Juru Growth Point is the main business center for the area and is located adjacent to the Mutoko road running from Harare and between Gutu and Mwanza wards. The administrative center for the Rural District Council is at Goromonzi.

The Zimbabwe office of the International Center for Research in Agroforestry (ICRAF) employs a field extension worker in the Chikwaka communal area. This officer has a mandate to offer technical and extension advice focusing on agroforestry to the farmers in this area. The officer also facilitates access to seed and seedlings for the MPT fodder trees from ICRAF to farmers. The Forestry Commission and COOPIBO also each employ a extension officer resident at Juru growth point with the mandate to encourage farmers to "grow more trees" by facilitating access to polyethylene bags, seed and seedlings for exotic timber and fruit tree species. The national agricultural extension agency, AGRITEX employs two extension officers for each of Gutu and Mwanza wards while Dzvete ward has one officer. The AGRITEX mandate is to provide technical, advisory and extension services for land use planning and soil conservation to the smallholder farmers. The Agricultural and Rural Development Authority (ARDA) has also deployed a dairy liaison officer to work with farmers as a general manager at the milk collection center at Juru growth point.

3.2 Survey Methods

3.2.1 Informal survey

The use of informal interview techniques to hold discussions with key informants and farmers was followed using Participatory Research Methods (PRM). Participatory Research Methods are based on the principle of allowing the target community to be a part of and influence the direction of the research project. This encourages a reciprocal, rather than hierarchical, relationship between the community and researcher (Chambers, 1992). The aims of the initial informal study were to familiarize the respondents and the researcher with the research subject. The main outputs included identifying the relevant choice variables and choice set composition, defining the appropriate decision making context and identifying sources of heterogeneity in the sample. The informal survey also facilitated development of a sample frame and refining of the formal survey instrument serving as a complement to the formal survey process that provided qualitative data to test the proposed hypotheses. Key informants included ICRAF resource people at the Harare office, the ICRAF field extension officer in Chikwaka, AGRITEX extension officers, the DDP liaison officer and farmers. A key component of the informal survey stage was the participatory rural appraisal (PRA) meeting held with a group of 30 farmers. A structured guide was used in this informal meeting to address such topics as economic and institutional conditions in the area, household economic activities and land allocation to various uses. Also addressed were uses and importance of livestock with particular reference to the dairy herd, including the main components of the dairy enterprise; activities and practices involved in dairy cattle feeding; adequacy of feed resources; and use of MPT fodder. In addition, discussions focussed on existing feed practices, important attributes of feed sources, feed constraints and seasonal factors. This interaction was also an opportunity to assess general attitudes of farmers and group behavior.

3.2.2 Formal survey and survey instrument

The second stage of the research project involved development and application of a formal survey using a questionnaire. This questionnaire was developed in light of the proposed theoretical models of adoption, as modified by the understanding provided by informal interviews with members of the target community. The questionnaire was pilot tested on fifty farmers, leading to a number of modifications. The final version of the questionnaire is given in Appendix I. Two enumerators and a supervisor who were residents of the area were recruited for the purposes of questionnaire application in the local language of *Shona*. The household survey was conducted over a two months period, between September and November 1999. Due to the length of the questionnaire, two visits to each household were necessary to avoid respondent fatigue. In some instances, additional visits were made for verification of information after supervisory checks on data consistency.

The survey instrument sought to acquire quantitative information to test the hypotheses formulated as the postulated models of adoption behavior. Based on the findings from the PRA discussion and the literature review presented in Chapter 2, the explanatory variables influencing the feed technology adoption decision are postulated to be economic and/or socio-economic variables. The economic variables postulated for this analysis are grouped under the headings of: scale of dairy enterprise, productivity, income sources, management, resource constraints and MPT investment. The socio-economic variables are described in the sections below as innovators and experience, wealth and risk management, and gender. These groups of variables are discussed further in section 3.6 in the context of farmers' characteristics and sample statistics. Further discussion is in section 5.2 in the context of the models postulated to test hypotheses and *a priori* expectations.

The questionnaire was split into two sections because of its length. Questionnaire one was designed to acquire data on general socio-demographic and socio-economic characteristics of the household, particularly on motivations and resource endowments that may affect adoption of technology. Questionnaire two collected data on feed-source specific attributes related to labor, land and cash demands and seasonal availability of these feed sources and factors. Season is an important variable in determining combinations of feed sources used by a given farmer at any time during the year because of the drastic qualitative and quantitative changes in feeds and in factor availability by season. For this study, the year is split into three seasons roughly determined according to feed source availability throughout the year namely, the late dry season (August – December, *Chirimo*), the wet season (January – May, *Zhizha*) and the early dry season (June – July, *Chando*). Agronomic constraints and management strategies are viewed to determine seasonal access to feed sources and the presence of producing cows (cows in milk) in a particular period. The presence of producing cows determines the use of certain feed sources, such as dairy concentrates that are given only when milking, because of their otherwise prohibitive cost. In contrast, dry season maize silage, for example, may only be available if maize is grown during the wet season and conserved in preparation for the dry season. All questions in questionnaire two were repeated for the three seasons to capture the variation consequent on the differences in decision making by season. The survey relied on farmer recall of data and asked questions about the specific period between August 1998 and July 1999, which covers the three seasons mentioned above.

3.3 Survey Subject Selection

The study focuses on analyzing the incidence of use of agroforestry fodder in the feeding regime practiced by members of the smallholder dairy scheme in Chikwaka communal area where ICRAF introduced this technology beginning in 1994. The Chikwaka Dairy Association was established in 1984. At the beginning of the field survey in August 1999, approximately 170 households were identified to be current members of the dairy association. This identification was conducted through purposive sampling, which involves selection of the sample on the basis of prior knowledge of the population and to suit the aims of the research (Babbie, 1973). The identified farmers can be defined loosely as those delivering milk to the collection center at Juru growth point at one time or other in the recent past (generally within the last two years). Key informant advice provided by the ICRAF field officer was critical in locating farmers since dairy center records only applied to current producing farmers for that cropping year who had delivered milk to the center at least once between July 1998 to the time of survey in September 1999. Identification was conducted by walking through each village in the three wards and visiting households that showed signs of dairy activity through the presence of milking sheds, hay sheds, pastures and dairy cows at the homestead. The first few householders visited in each village then cited other dairy farmers within the village and neighboring villages with dairy activity, giving a series of contacts with households that occurred in a "snow-ball" fashion to identify the total population.

It was decided to administer the questionnaire to the total identified population of Chikwaka dairy farmers. The response rate was 100 percent of the households identified. Of the original 170 household, responses, 118 are used in the final analysis and the other 52 responses were treated as pre-test cases as changes in the questionnaire were made after the initial survey of these households. The structure of the sample, in the final group of 118 farmers, according to administrative ward and village is presented in Table 3.1.

Table 3.1: Number of Households (HHs) in Final Survey Sample by Administrative Ward and Village

Mwanza Ward		Gutu Ward	
Village	**No. of HHs**	**Village**	**No. of HHs**
Chigora b	3	Bungu	1
Chinanda	1	Chigora a	1
Chipikiri	5	Chirima	3
Chiwocha	1	Chitembo	1
Choruwa	6	Goremusande	1
Goremusandu	15	Gutu	2
Gosha	2	Gwamura	1
Gumbodete	1	Kadyamadare	1
Koromani	2	Mabvudzi	1
Majoka	1	Manhudzi	1
Makuku	2	Marimo	1
Mapfumo	4	Mavhudzi	1
Marimo	1	Mhondamapanga	1
Marimo B	1	Mhondanadango	1
Masarurwa	1	Mujuru	1
Masawi	3	Murungweni	1
Matyaire	11	Muzhona	1
Muchemwa	1	Ngorima	1
Mudhiwa	4	Rukaingwa	1
Muhwati	2	Tefere	1
Murambwa	5	Ururu	2
Murape	1	*Sub-total*	*25*
Musarurwa	4		
Musaruziwa	1	**Dzvete Ward**	
Mwanza	1	**Village**	**HHs**
Ndamba	5	Murungweni	1
Nekati	1		
Noamba	5		
Tunha	2		
Sub-total	*92*		
Total Number of Households		**118**	

3.4 The current dairy cattle feeding practice

3.4.1 Cattle feed requirements

Two major components of a cow's diet are dry matter (DM) and crude protein (CP). The feed requirements for a mature dairy animal dictate that the animal consumes about 3% of its body weight of dry matter (DM) daily (Burgers, Dzowela and Franzel, 1997). This would constitute about 9 to 10 kilograms of DM for an animal weighing 300 kilograms. The crude protein consumption is calculated relative to the dry matter intake of the cow and should not fall below a critical threshold of 6 to 8% of DM intake in order to support rumen microbial digestion (Dzowela, 1997). When the crude protein of feeds falls below this critical threshold, the animal's appetite is depressed and forage intake is reduced, thus reducing animal productivity. The National Research Council (1989) has suggested that 11 to 12% CP content is adequate for maintenance of the cow and for moderate live weight gains, whereas 14 to 16% CP is required for producing (in milk) dairy cattle.

3.4.2 The six main feed sources used in Chikwaka Communal Area

The six main livestock feed sources used by smallholder dairy farmers, identified through PRA discussions and from the literature (Burgers, Dzowela and Franzel, 1997; Dube 1995), are communal grazing, crop residues, maize, purchased concentrates, pasture grasses and legumes and multi-purpose tree fodder (MPT). Various combinations of these six feed sources are used throughout the year in an attempt to meet the dry matter, crude protein and other livestock feed nutrient requirements of the dairy herd. The lower value feeds containing high levels of dry matter relative to crude protein content are used as the basal diet for the animal whilst the high protein content feeds are used as supplements to ensure that adequate crude protein levels are consumed by the animal.

3.4.2.1 Communal grazing

For the majority of communal area households, extensive grazing on the communal grazing and woodland resource, with grass and trees, is the major source of livestock nutrition. Pressure on grazing lands, which are a common property resource, has mounted due to increased population and the need to clear land for agriculture and settlements. Insufficient communal grazing land is an important constraint to livestock production (Clarke, 1994). In addition, the nutritive value and quantitative availability of this feed resources declines rapidly from the end of the wet season in May to the peak of the dry season in October. During the wet season the crude protein content of range grazing is 8 to 10% of the dry matter (DM). This value declines to as low as 1 to 3% during the dry season which is far below the critical threshold of 6 to 8percent CP (Dzowela, 1997).

It is common for Chikwaka farmers to seek permission to graze cattle or to collect hay from neighboring commercial farming areas with relatively abundant grazing resources. It is also common for Chikwaka smallholder farmers to purchase hay from neighboring commercial farms. Grass collected from communal areas that are considered as 'no man's land' (such as contour bunds - *madhunduru*) is conserved and stored as hay for dry season feed.

3.4.2.2 Crop residues or stover

Chikwaka communal area is located in the relatively high potential agro-ecological region (NR II and III) where crop production is good and livestock rely on crop residues for up to fifty percent of their energy requirements. Maize stover, the residue after harvesting the maize crop, represents a valuable resource to households for feeding cattle (Chivaura-Mususa, Campbell and Kenyon, 1997). In general, crop residue, particularly maize stover, is available for use because maize is a staple crop. In the higher potential agro-ecological regions, maize stover yields average 2.9 tons per hectare. In the lower potential agro-ecological regions (NR IV and V), crop production is constrained by erratic rainfall and cattle depend on the browse component of grazing to a much greater extent. In this case, crop residues meet only twelve percent of cattle energy requirements. The amount of crop residue exclusively available to an individual household's cattle is in direct proportion to the area planted by that household to maize. However, all the community cattle also benefit from free roaming across fields during the dry season until the first day of November each year when cattle are required by law to be controlled in anticipation of the new season's crops. In addition, crop residues may find an alternative use as a source of energy by households facing fuel wood constraints. By the time of the subsequent wet season, crop residue supplies stored from the previous harvest have been depleted in most cases.

Cereal crop residues generally have a poor feeding value, similar to that of range grazing in communal areas, with only about 3 percent crude protein content. Households collect and store residues to feed to cattle and these are sprinkled with salt to taste and mineral supplements. In many cases, urea is also added to the crop residues as a source of crude protein (CP) content.

3.4.2.3 Purchased concentrates

Purchased commercial feeds, such as dairy concentrates and dairy meal, provide a good source of protein and other livestock feed nutrients, particularly during the dry season when the major sources of dry matter (grazing, hay and crop residues) are very low in nutrient value. A fifty kilogram bag of dairy meal, based on cotton seed cake, contains about eight kilogram of crude protein (CP) (Dzowela, 1997). Dairy cattle that are producing milk for income generation are valued enough to justify feed supplementation by purchased concentrates. Farmers say that they are recommended to feed milking cows an average of three kilograms of concentrates per day or dairy meal mixed with crushed dry maize. Greater or smaller rations may be administered to milking cows depending on the cow's actual milk output and cash constraints.

3.4.2.4 Pasture grasses and legumes

Many herbaceous and woody tree legumes and pasture grasses have been tried as a source of protein nutrition for livestock. The national agricultural extension agency AGRITEX has encouraged dairy farmers to grow napier grass pastures and to fortify grazing areas with pasture legumes for livestock supplementation. Examples of recommended pasture legume species are *Stylosanthes sp., Siratro sp.,*and *Lablab purpureum*, velvet beans, cow peas and others. Farmers that are members of smallholder dairy schemes have been specifically recommended to grow 2.6 hectares of napier grass each to sustain a productive dairy herd. The preparation of a napier grass pasture was in fact a prerequisite for access to the Heifer Project International (HPI) dairy cows that were given as starting capital for the new market-oriented dairy farmers. Most farmers in these schemes, such as in Chikwaka, have been found to comply with these recommendations, although pasture areas tend to be much smaller than was recommended (Dube, 1995). Napier grass is the most widely grown pasture grass that is high yielding, between 12 and 15 tons per hectare and has a crude protein range of 9 to14 percent (Chakoma, 1995). Pasture grasses and legumes are mostly available to feed cattle during the wet season when leaves are blooming. Storage for dry season use is in direct proportion to area planted and management. According to Dzowela (1997), herbaceous legumes have generally failed to persist in these low external input systems.

3.4.2.5 Multi-purpose tree fodder banks

Multi-purpose tree (MPT) fodder species have been developed on research stations as an alternative source of quality (high protein) livestock nutrition particularly for the dry season when severe feed shortages are faced. MPT 'fodder banks' are a variant of the agroforestry practice of alley cropping that involves growing of food crops between leguminous nutrient-cycling trees and shrubs which are pruned periodically during the cropping season to reduce shading and to provide green manure and fodder for livestock (Burch and Parker, 1991). Introduction of MPT fodder trees for on-farm farmer led trials began in 1994 in Chikwaka communal area (Burgers, Dzowela and Franzel, 1997). The MPT species that have been tested in biophysical experiments for establishment by ICRAF in Zimbabwe include *Leucaena leucocephala* cv Cunningham, *Leucaena pallida, Cajanus cajan, Acacia Anguistinia* and *Calliandra Calothyrsus*. Crude protein content of the MPT fodder is about 26% for leaves of *Acacia Anguistinia*, about 25% for the leaves of *Leucaena leucocephala*, and about 22% for the leaves of *Calliandra Calothyrsus*. The stems and older plant parts have much lower crude protein content.

Many farmers who are members of the Chikwaka dairy association grow MPT fodder for cattle feed supplementation. The important benefits of these trees in the Zimbabwean farming system are in reducing the costs of commercial feed supplements, thus making market dairying viable (Burgers, Dzowela and Mafongoya, 1997). MPT fodder has the favorable characteristic of having a high nutrient value. However, drying of MPT fodder to store for use in the dry season results in a reduced crude protein content and reduced digestibility. A potential constraint to use of MPT fodder in the dairy feed system is the presence of anti-nutrient factors that reduce palatability and digestibility. Farmers have reported that cows selectively feed on other feeds ignoring those that may seem to have an unfavorable 'flavor' particularly after drying the plant material. In on-station research, Dzowela (1997) observed some depression in the animals' dry matter consumption when animals were fed *Calliandra Calothyrsus* as their only source of crude protein.

MPT fodder tree species achieve higher potential yields in the second year after planting (Dzowela, Burgers, Tapfumaneyi and Chikura, 1997). MPT fodder is mostly available to feed cattle during the wet season when leaves are flushing. At the end of the wet season forage must be cut and conserved for storage otherwise plant material will be lost due to leaf fall. During the dry season, the fodder trees become deciduous in response to climatic stress; for example many species will succumb to frost damage. Harvesting of MPT fodder to store for dry season use is constrained by total fodder output which depends on the area planted. Burgers, Dzowela and Franzel (1997) recorded average fodder yields of 930 kilograms of dry matter per hectare planted for eight farmers included in on-farm trials. To illustrate the fodder outputs obtained by the farmers in the survey sample for this study, let us assume the same yields as for the above group.

Given that the sampled farmers have on average 0.105 hectares (0.248 acres) planted to MPT fodder trees, their tree fodder output for the year should be equivalent to about 98 kilograms of DM. This would constitute about 33 days of feeding for one cow supplemented at a rate of 30% (i.e. by 3 kilogram per day). Low fodder outputs may occur due to agronomic constraints such as poor soil fertility, inadequate moisture and problems of plant spacing and pests (particularly nematodes and termites). Management and resource constraints are also important in determining fodder yields. These may largely be due to limited experience with seedling and tree growing, inadequate labor to grow and nurture seedlings and trees in the wet season, and inability to control browsing of unprotected trees by stray livestock, particularly goats. All the factors above may contribute to poor survival rates of trees as well as poor yields. For example, Dzowela (1997) shows from the results of on-station trials that management factors such as deferring wet season cutting time from January to April, result in significant fodder yield increases and dry season fodder re-growth.

To alleviate land and labor constraints to the production of MPT fodder, farmers normally inter-crop the trees with pasture grasses and legumes so that tending operations are performed simultaneously.

3.4.2.6 Maize

Maize is a staple food that is cultivated by all households for home consumption. Maize may also be fed to cattle that are highly valued, such as income generating dairy cattle. It is common for most farmers to allocate a separate acreage of maize solely for cattle feed which is either used to make silage for dry season feed or from which the grain is dried and ground into "crushes". Silage, a fermented mixture of mainly maize and molasses, is high in protein content. Silage is made near the end of the wet season and is normally fed to animals from about June until supplies run out, which is normally by about August for most farmers. Crushed maize is mixed with purchased dairy meal and this may be fed throughout the year to dairy cows in milk. Where dairy cattle are not allocated a separate maize acreage for feed, the household will often sacrifice some of its own maize harvest to feed lactating dairy cows.

3.4.3 Seasonal factors in feed source use

Feed source availability varies drastically, both quantitatively and qualitatively, from wet to dry season. Wet season feed regimes include: fresh range grazing; fresh cut and carry pasture grasses and legumes and MPT fodder; maize crushes; purchased concentrates fed to milking cows; and crop residues for farmers who manage to store enough from the previous harvest to last through to the next wet season. Most of the plant-based feed resources are high in crude protein content when fresh and provide adequate dry matter in the wet season. Dry season feed regimes incorporate: maize crushes sometimes mixed with purchased concentrates; dried pasture grasses and legumes and MPT fodder; silage made from fresh maize; post-harvest crop residues; and hay conserved from grass collected from communal areas and neighboring commercial farms. The main source of crude protein for cows that are producing milk is purchased concentrates. Other high protein feed sources are MPT fodder and maize silage where available. The other sources of dry season feed are mainly dried plant materials that are generally low in protein content.

Quantitative feed availability for the dry season is largely determined by investment of land and labor resources and management. This is mainly achieved by planting a sufficiently large acreage of maize, MPT fodder and pasture grasses and legumes such that some feed may be conserved from the wet season in preparation for the dry season. Also important is management of cutting times and methods during the wet season to ensure tree and plant leaf re-growth and management of agronomic constraints as well as protecting plants from uncontrolled browsing by stray animals. Possibilities for harvesting and conserving fodder (grass for hay, crop residues, MPT, pasture grasses and legumes) during the wet season when the plant material is still of good nutritional value are constrained primarily by labor availability during this peak period of cropping activities. Collection of hay can be very time consuming, particularly because of distances that need to be traveled to access range land and the quantities that need to be collected to ensure sufficient supply for the long dry season. Labor is also a constraint to the collection of crop residues to store as livestock feed after the harvest.

Liquidity constraints expressed through the lack of availability of cash will determine the feasibility of purchasing commercial feeds for livestock supplementation and hiring manpower to augment family labor. Cash availability is also closely linked to having cows that are producing milk for sale and this is determined by management and is seasonal, depending both on successful breeding of cows to induce lactation and adequate feeding to ensure milk production. It should be noted, however, that the breed and other physiological characteristics of the dairy cow will also determine the ability to induce lactation. Liquidity as a seasonal phenomenon in Chikwaka communal area is also closely tied to crop harvest periods when crop sales occur. It also reflects transfers or remittances from wage earning family members, sale of crafts and bricks, and sale of relatively liquid assets such as cattle, goats and other small livestock. Many of these are counter seasonal activities, occurring in slack agricultural periods due to labor constraints.

3.5 Definition of feed technology alternatives

The choice set of feed alternatives available to the farming households is assumed to be identical for all households since all six identified main feed sources are known and feasible to all sampled households. Table 3.2 below presents the results of counts of households observed from the survey to use each of the six main feed sources.

Table 3.2: Number of households by feed source used each season

Feed source	**Number of Households**			
	LD	**W**	**ED**	**Mean %**
1.Communal grazing	118	118	118	100%
2.Crop residue/stover	104	64	101	74%
3.Concentrates	89	87	93	76%
4.Past grass & legume	98	102	100	85%
5. MPT fodder	68	80	72	64%
6.Maize	116	79	113	87%

Footnote: LD=Late dry season, W=wet season, ED=Early dry season

The six identified major livestock feed sources were used to define composite feed technology bundles that are different combinations of six or fewer of these feed sources. Preliminary analysis of the data collected from the survey indicated that 18 possible combinations of the six feeds were observed. However, given the lack of variation in use of many of the feed sources observed from inspection of the figures in Table 3.2, it was decided to consider only the incidence of use or non-use of MPT fodder and purchased concentrates to group households by feed technology choice. The feed sources of communal grazing, crop residues, pasture grasses and legumes and maize are thus held constant for every observation. In addition to the lack of variation in use of these four feed sources, a number of reasons justify this grouping of farmers by feed technology choice. Some of these arose in the PRA discussions and others resulted from preliminary data analysis.

The low incidence of use of crop residues in the wet season is observed because crop residue supplies stored from the previous harvest do not last until the wet season before the new crop is harvested. Maize is used as a cattle feed, even where dairy cattle are not allocated a separate maize acreage for feed, the household will often sacrifice some of its own consumption of the staple maize for the dairy cows.

In addition, communal grazing, which is viewed as an open access activity, is available for all to use at relatively low cost to the individual farming household. Its use for open grazing following the cropping season is customary practice. Even where households will not let their dairy cattle graze in communal grazing areas, grass is collected from areas that are considered as 'no man's land' (such as contour bunds - *madhunduru*) to conserve as hay for dry season feed. As well, officials of the Dairy Development Project (DDP) specified that farmers plant napier grass fodder pastures for dairy cow maintenance as a condition of entry into the scheme (Dube, 1995). Therefore, every farmer has introduced grass and/or legume pasture. The pastures, being perennial, tend to regenerate year after year with the rains and thus the majority of farmers still manage to harvest some pasture grass to feed dairy cattle. Finally, the dependent variable in this analysis is a simple yes or no measure indicating use of a feed technology with no consideration for intensity of use. Therefore, it is impossible to capture significant levels of use of any of these feed sources, particularly those that may be considered to be readily available and of relatively low value, such as the communal grazing and crop residue.

3.6 Sample description by feed technology choice

From the preceding discussion in section 3.5, it is apparent that important trade offs occur between MPT fodder and purchased concentrates in the choice of feed technology used by farmers. The resulting alternative feed technology bundles available to farmers are: 1) use of both MPT and concentrates (Both); 2) use of concentrates and no MPT, (Conc); 3) use of MPT and no concentrate and (MPT); 4) use of neither (Neither). The feed technology bundles can be broadly considered as cash-requiring versus labor-requiring technologies. In this context: 1) is a combination of both cash and labor requiring, 2) is cash requiring, and 3) is labor requiring. Tables 3.3 and 3.4 below present sample statistics of the data collected to illustrate the economics and the underlying socio-economic factors of choosing among the four feed technology possibilities, in the both wet and dry seasons. Specified variables are postulated to represent the following general factors: scale of dairy enterprise; efficiency; income sources; management; resource constraints (such as liquidity and credit constraints, labor availability, land availability); MPT investment; innovation and experience; wealth and risk management; and gender.

From Table 3.3 we observe that farmers in the group using both MPT fodder and purchased concentrates (Both) have the largest herd sizes, as shown by the mean total cattle herd, which includes both dairy and non-dairy animals. This group of farmers exhibits the second earliest mean start date of experimentation with MPT fodder planting, after the 'MPT' alone group, and the largest mean area planted to MPT fodder. This might indicate these are 'innovators'. This group appears to represent relatively wealthy farmers that have diversified their cattle feed source base and shown a willingness to adopt new techniques like MPT fodder, possibly because of their ability to absorb risks. Only 48 percent from this group cite milk revenue as their primary income source, compared to 70 percent for the group using 'Conc' alone. The "Both" group has the largest number of farmers citing land constraints as the major reason for their livestock feed problems. On average, 45 percent of farmers cite land problems in this group, whilst the whole sample mean response to this question is 35 percent and responses in the other three groups fall below this mean.

The dairy farms using concentrates only, 'Conc', have the highest mean dairy herd and highest absolute number of producing cows. Seventy percent of these farmers indicate that milk income is ranked as the most important income source for the farming household compared to 42 percent for the whole sample. This group of farmers use relatively more cash inputs to purchase feeds and has the largest area allocated to all pasture but the smallest area allocated to MPT fodder. Farmers in this group generally started experimenting with MPT fodder much later than all other groups of farmers. Indeed, the mean start date for the 'Conc' of 1998.1 is more than a year later than the mean start date of 1996.9 for the whole sample. Farmers that use only MPT fodder and no purchased concentrates have a small dairy herd of 1.69 cows on average compared to the sample mean of 2.63.

Table 3.3: Economics and Socio-economic Factors in Feed Technology Choice–Wet Season

Variable	*Definition*	*Sample n=118*	*Both n=67*	*Conc n=20*	*MPT n=13*	*Neither n=18*
Scale of dairy						
DARYHER	absolute number of dairy cows owned	2.63	2.88	3.40	1.69	1.47
INMILK	number of dairy cows actually producing milk	1.12	1.30	1.75	0.46	0.21
Efficiency						
INMDAR	ratio of cows in milk to dairy herd	0.390	0.481	0.485	0.149	0.116
Cash availability						
DELIVY	farmer receiving cash income from dairy = 1	0.356	0.418	0.45	0.154	0.158
Income source						
MILK1ST	dairy considered primary income source = 1	0.42	0.48	0.70	0.31	0.00
CROP1ST	crops considered primary income source = 1	0.16	0.10	0.005	0.15	0.53
Land availability						
LANDPRB	feed problem due to grazing land shortage = 1	0.35	0.45	0.25	0.23	0.16
MAIZTOT	ratio of maize acreage to total land holding	0.410	0.388	0.404	0.463	0.436
Labor availability						
MAIZLAB	HH members per acre of maize planted	2.328	2.251	2.740	1.878	2.479
HHSIZE	Household size – number of people	5.87	5.77	6.04	5.77	6.26
MPT Investment						
MPTAREA	Area planted to MPT fodder (acres)	0.248	0.307	0.193	0.246	0.125
Management						
RECORDY	Farmer records activities and transactions = 1	0.37	0.38	0.35	0.54	0.21
LFAY	farmer attended last dairy management meeting = 1	0.46	0.48	0.55	0.38	0.37
Innovators and experience						
MPT1ST	year first planted MPT fodder	1996.9	1996.5	1998.1	1996.4	1997.2
JOINDAR	year joined dairy association	1993.7	1993.2	1994.8	1994.2	1994.3
Gender						
PRDSEXF	female HH member responsible for dairy = 1	0.65	0.64	0.80	0.54	0.58
Wealth						
HERDSIZE	total number of cattle held (plus non-dairy)	6.08	6.93	6.15	4.38	3.95
SCOTCHY	HH owns a scotch cart (ox-drawn cart) = 1	0.474	0.49	0.30	0.62	0.53

Footnotes: The values presented in the table are calculated variable means; Both = purchased concentrates and MPT fodder; Conc = purchased concentrates alone; MPT = MPT fodder alone

Farmers in this group have the smallest proportion of their total dairy herd producing milk with an average of about 15 percent. In the "MPT" only group, 31 percent cite milk as the primary income source whilst another 31 percent cite market gardening and 15 percent cite crop income as the main source. This group exhibits the earliest start date for experimenting with MPT fodder planting and the second largest mean area planted to MPT fodder.

Farmers in the "Neither" group appear to represent the marginal dairy farmers. None of the farmers cite dairy income as most important, compared to the whole sample mean of 42 percent for which this is the case. Crop income is the most widely cited primary income source cited by 53 percent of farmers in this group. The lowest values are observed in this group for dairy herd size, cows in milk, MPT pasture area and total cattle herd. The major wealth indicator, total cattle herd, has a mean of 3.95 for this group which is much lower than the sample mean of 6. 08. Mean family size is highest in this group. This group seems to represent farmers who are not concentrating efforts on the dairy enterprise and are thus may be less motivated to diversify their feed technology by incorporating MPT fodder or less likely to incur costs by purchasing concentrates.

The means of dry season variables for each group follow similar trends to those discussed for the wet season above (see Table 3.4). The important difference is in the generally lower productivity levels in the dry season as shown in the values for INMILK and INMDAR compared to the wet season. Higher productivity is observed, in the dry season, only among farmers who feed purchased concentrates compared to the wet season. This possibly reflects better management of farmers to ensure that cows are lactating during the dry season and that adequate feeding, through conservation and storage of feeds, is provided to these to maintain productivity.

In the dry season in general, 77 percent of the farmers use purchased concentrates compared to 74 percent in the wet season. It appears that purchased concentrates are used to alleviate dry season feed shortages and that these may be financed through proceeds from crop sales from the recent harvests (April-May) or through the sale of livestock. There is also a reduced level of use of MPT fodder in the dry season, possibly due to reduced availability. Feed availability of plant based feeds (grazing and pasture plants) is much lower during the dry season when most biomass is dry and nutritionally poor, and quantitative availability depends on farmers having stored some feed from the wet season.

Table 3.4: Economics and Socio-economics Factors in Feed Technology Choice–Dry Season

Variable	*Definition*	*Sample* *N=118*	*Both* *n=58*	*Conc* *n=33*	*MPT* *n=12*	*Neither* *n=15*
Scale of dairy						
DARYHER	absolute number of dairy cows owned	2.61	2.78	3.39	1.21	1.25
INMILK	number of dairy cows actually producing milk	1.15	1.23	1.82	0.21	0.14
Efficiency						
INMDAR	ratio of cows in milk to dairy herd	0.423	0.467	0.600	0.111	0.119
Cash availability						
DELIVY	farmer receiving cash income from dairy = 1	0.347	0.414	0.424	0.167	0.007
Wealth						
HERDSIZE	total number of cattle held (including non-dairy)	6.03	6.70	7.08	2.708	3.96
SCOTCHY	HH owns a scotch cart (ox-drawn cart) = 1	0.47	0.53	0.36	0.50	0.43
Land availability						
LANDPRB	feed problem due to grazing land shortage = 1	0.35	0.0.38	0.42	0.25	0.14
MAIZTOT	ratio of maize acreage to total land holding	0.410	0.385	0.414	0.440	0.429
Labor availability						
MAIZLAB	HH members per acre of maize planted	2.328	2.322	2.368	2.132	2.444
HHSIZE	Household size – number of people	5.87	5.717	5.931	6.00	6.21
MPT Investment						
MPTAREA	Area planted to MPT fodder	0.248	0.312	0.176	0.287	0.005
Management						
RECORDY	farmer keeps records of activities/transactions = 1	0.37	041	0.38	0.42	0.14
LFAY	farmer attended last dairy management meeting =1	0.46	0.43	0.55	0.50	0.36
Innovators and experience						
MPT1ST	Year first planted MPT fodder	1996.9	1996.5	1997.5	1996.5	1997.2
JOINDAR	Year joined dairy association	1993.7	1993.0	1994.1	1995.2	1994.9
Gender						
PRDSEXF	Female HH member responsible for dairy = 1	0.65	0.64	0.73	0.58	0.57

Footnotes: The values presented in the table are calculated sample means; Both = purchased concentrates and MPT fodder; Conc = purchased concentrates alone; MPT = MPT fodder alone

In general, however, of the whole population of Chikwaka dairy association members, the number delivering milk to the collection center at any one point in time is rather low. The average number of farmers delivering milk at any time is around 36 percent for the wet season and 35 percent for the dry season for this sample of the population of Chikwaka dairy association members. This tendency may reflect varying levels of motivation of members in the dairy scheme, as well as variations in management, resource endowments and poor dairy cattle breed performance. Another reason for this feature may be recent dairy cattle deaths suffered by some farmers due to tick-borne diseases.

Chapter 4 - - Theoretical and Empirical Framework

The following discussion, which draws on the work of Ben-Akiva and Lerman (1985), links the research problem and the specific research questions formulated in the preceding chapters to principles derived from economic theory in order to formulate economic models and testable hypotheses that are amenable to empirical analysis. Underlying the question of adoption and its determinants is economic decision theory. We assume a rational decision maker with consistent, transitive preferences, who seeks to optimize given some objective function. Household production theory, which views the household as a consumer and producer facing various resource constraints (including time availability), is adapted for the formulation of the usual problem of constrained utility maximization. This approach is deemed relevant to the smallholder dairy farmers that are the focus of this study in order to assess the optimal combination of activities and purchased inputs in the production of outputs used in the cattle feed system.

The analytical approach followed focuses directly on the concept of the indirect utility function based on revealed preference data. Resource constraints and socio-economic characteristics of farming households are postulated as arguments of the indirect utility function to explain variation in choices. Random utility theory (Manski, 1977) is adapted for the specification of a probabilistic choice model, which is the basis for the empirical discrete choice models, in order to account for behavioral inconsistencies that result in errors between observed and predicted choices. The discrete choice model postulated to test the hypotheses is specified as the multinomial logit models. The implication of the underlying assumption of the independence of irrelevant alternatives (IIA) is also discussed.

4.1 Choice theory

The general purpose of the theory is to develop a predictive model of the choice behavior of a group of individuals. This aggregate behavior is, however, a result of the decisions of individuals or households.

4.1.1 Elements of the decision making process

Any given choice can be viewed as the result of a sequential decision making process by the individual or household. This process takes into account the following elements: 1) the decision maker 2) the alternatives 3) the attributes of the alternatives and 4) the decision rule applied.

The decision maker is synonymous with the economic agent of concern. This may be an individual, firm or group such as a household. Differences in decision making processes among individuals or households are due to differences in preferences and circumstances (physical, socio-cultural, socio-demographic and socio-economic). The decision maker draws a choice from a non-empty set of mutually exclusive and collectively exhaustive alternatives which are determined by his/her environment. From the universal set of alternatives, a given individual considers the subset that is his/her choice set. This includes all the alternatives that are feasible for and are known by the decision maker. A choice set may be continuous, such as quantities in a commodity bundle, or discontinuous, as in the case of the discrete alternatives that are the focus of this study. Preferences over alternatives are viewed as being determined by the attributes and attribute values. For the case of homogenous continuous alternatives, the attribute values reduce to quantities, whereas for the case of heterogeneous discrete alternatives, each alternative is characterized by its attributes and the attribute values.

As long as a choice must be made between two or more alternatives, a decision rule is required in order to arrive at a unique solution. A decision rule based on utility is applied and utility is viewed as the measure of the attractiveness of a given alternative. This results in the formulation of a choice process that is amenable to mathematical and statistical analysis. The assumed single valued nature of the objective function allows for compensatory offsets or trade-offs by the decision maker when comparing different attributes of alternatives. As such, this implies that given a choice among alternatives with distinct utilities, the decision maker will select the alternative with the highest utility. Underlying this conclusion is the concept of a rational decision maker. Rational behaviour in economic consumer theory refers to a decision maker with consistent and transitive preferences, such that under identical circumstances a choice will be repeated.

4.1.2 Economic theory of consumer behavior

Consumer theory allows us to translate assumptions about preferences for commodities or services into demand functions that depict the behavior of consumers in particular situations. The demand functions provide an expression for the chosen optimal consumption bundle, given constraints, and are generally viewed as $Q = \{q_1, \ldots\ldots, q_z, p_1, \ldots\ldots, p_z, m\}$ where $q_1, \ldots\ldots, q_z$ are the quantities of each of the commodities and services, $p_1, \ldots\ldots, p_z$ are the prices of each of the commodities and services, *m is* the consumer's income. These quantities are generally assumed to be nonnegative continuous variables, but may also be discrete variables in the sense that consumption of one or more of the commodities may be zero, as discussed later. The demand functions can be substituted into the utility function *U(.)* which is not observable, to obtain the indirect utility function *V(.)* at the given price and income levels. In empirical applications, where the parameters of demand functions are estimated from data on different consumers, it is necessary to specify how utility functions vary among consumers apart from the effects of prices and income. This variation is due to preferences and socio-economic characteristics and these are thus incorporated into demand estimation. Random error terms are also incorporated in estimation to account for the effect of unobserved influences and measurement error on predicted choices.

4.1.3 Relevant extensions of consumer theory

Although all commodities and services that an individual or household consumes are related through the budget constraint, it is possible to impose restrictions on this dependence in a partial equilibrium context. Strotz (1975) proposed the concept of the utility tree that allows commodities to be grouped in branches with *weakly separable* utilities. This implies that the marginal utility of consumption of items within one branch is independent of the marginal utility of consuming items in a second branch. This allows us to analyze one category of related goods in isolation from other goods (Moschini and Moro, 1993). Behaviorally, this represents a sequential or two-stage budgeting process where initial allocations are made to the branches and in the second stage, allocations are made within branches. Therefore, the derived demand functions we consider ultimately only contain variables pertaining to related commodities, those within the same branch of the utility tree (Deaton and Mullbauer, 1980).

In conjunction with the proposition by Muth (1966) of commodities being purchased as inputs into a household production process with non-market goods as outputs, Lancaster proposes technical relationships between commodities and attributes and postulates that commodities and services are purchased for their attributes as inputs into household production. Becker (1965) adds the time constraint and extends utility maximization to encompass human activity incorporating the purchase of market goods and services and use of time and other attributes such as comfort or safety (Ben-Akiva and Lerman, 1985). Arising out of the work of Gorman (1956), Becker (1965) and Lancaster (1966), is what is now termed *household production theory* which provides a useful approach to modeling household behavior.

4.2 Household production theory

4.2.1 Overview

The typical smallholder farm household is a producer and consumer of many commodities that are absorbed and cycled within the system to contribute to its overall well-being and productivity. The household production framework as proposed by Michael and Becker (1973) cited by Deaton and Mullbauer (1980), is adopted and applied as the underlying behavioral model. This theory views the household as both producer and consumer and accounts for the constraints on available time as well as income and other resources as determinants of choice in the utility or welfare maximization problem. Singh *et al* (1986) applies the model of Michael and Becker (1973) to household agricultural production. Cavendish (1997) reviews the approach of the household production model approach in the context of Zimbabwean households' multiple resource uses in a dynamic and risky environment. His model is simplified by ignoring risk and dynamics and collapsing the model into a static form. A similar approach is adopted by Hatton MacDonald (1998) in the valuation of fuel wood resources using a site choice model of fuelwood collection. The simpler household production models assume independence of the household production and consumption decision. However, Hatton MacDonald (1998) suggests that consumption decisions are influenced by production decisions, for example through marketed surplus.

4.2.2 Components of the household model

Following the approach of Deaton and Mullbauer (1980) we assume *weakly separable* sub-utility functions for the various components in the household economy in order to isolate household production-consumption decisions for the dairy feed activity. Interaction with other household economy categories is considered only in terms of the contribution to dairy feed activity. In this study, the choice of technology for dairy cattle feeding is viewed as the household's resource allocation towards solution of a subset of the optimization problem. The components of the household's micro-economic model are the cost function, the resource budgets, and the utility function that are related to its constrained optimization problem (Deaton and Muellbauer, 1980).

4.2.3 The constrained optimization problem

We assume that, in trying to maximize utility, the household allocates available resources subject to constraints to production and consumption activities in response to the returns from each activity given its associated risks (Luckert *et al*, 1997). The objective function in this case is defined as the utility derived from adopting a given feed technology bundle for the dairy enterprise. A constrained optimization problem can thus be postulated and first order conditions solved yielding demand relationships for each activity in the utility function. The demand functions are a function of all prices for production inputs and consumables, labor, income and production technology. The first order conditions indicate that utility is maximized when the ratio of marginal utilities for each pair of inputs into the utility function is equated to the ratio of the market prices of those activities; the household stays within the budget constraints and operates on the production frontier; the household produces the optimal combination of goods; and the household allocates variable factors efficiently amongst potential uses. The solution to this primal optimization problem yields demand functions that can then be substituted into the original utility function to obtain the indirect utility function.

4.3 Discrete choice and random utility theory

4.3.1 Overview of discrete choice theory

At any given point in time, the household must make a choice within the feasible choice set of feed technology bundles that are discrete alternatives. Discrete choice theory concerns such choice situations where the decision maker draws a choice from a non-empty set of mutually exclusive and collectively exhaustive alternatives and consumption of one or more commodities is required to be zero (Ben-Akiva and Lerman, 1985). Due to the discrete nature of the alternative commodity bundles, the solution to the household's primal optimization problem outlined in section 4.2.3 yields a corner solution. Consequently, an operational model consists of a parameterized utility function in terms of observed independent variables and unknown parameters, and the values of the parameters estimated from a sample of observed choices made by the decision makers. According to this theory, we expect that an alternative i, will be chosen over another j if the utility associated with i is greater than or equal to utility from the j alternative. This utility is a function of the cost of the alternative, its attributes and of the characteristics of the decision maker relative to preferences, perceptions and socio-economic environment. As such, revealed preference data on the variables collected through the formal survey can be used to specify the indirect utility function for the empirical model.

4.3.2 The basis of the random utility model

There is uncertainty concerning the precise level of utility arising from any given alternative, which suggests that a random component may be associated with the observed household choices

(Ben-Akiva and Lerman, 1985). The systematic component of utility is a function of observable attributes of commodities and individuals, while the random component captures variations in choice due to within- and between-individual variance, omitted variables, measurement errors and imperfect information (Manski, 1973). There is, therefore, a need to apply probabilistic choice concepts, such as random utility models, to explain behavior (Train, 1986). In random utility theory, the expected utility of a good is viewed as a function of the attributes of the good, the relevant characteristics of the decision maker and some random component.

The choice of an alternative i is one of a finite set of alternatives in the household's choice set C_n. A rational household, n chooses an alternative i such that the utility obtained from i is greater than or equal to the utility derived from any other alternative j in the choice set C_n. This can be written as follows:

$$P_n(i \mid C_n) = P_r[U_{in} \geq U_{jn}, \forall_j \in C_n] \text{......................................} (4.1)$$

Given that we are uncertain about actual choice and utility of each alternative, we can express the random utility of an alternative as a sum of observable (systematic) and unobservable components as follows:

$$U_{in} = V_{in} + \varepsilon_{in} \text{..} (4.2)$$

Where U_{in} is person n's utility of choosing alternative i, V_{in} is the systematic component of utility, and ε_{in} is a random component. Expression 4.1 can be re-written as follows:

$$P_n(i \mid C_n) = P_r[V_{in} + \varepsilon_{in} \geq V_{jn} + \varepsilon_{jn}, \forall_j \in C_n] \text{..............................} (4.3)$$

The random component is assumed to be independently and identically distributed (IID) according to a particular probability distribution. The assumption of IID random errors results in a simple scaleable model where the choice probability of an alternative i is only a function of the differences

$$V_{in} - V_{jn}, j \neq i, j \in C_n$$

V_{in} is assumed to have a linear form:

$$V_{in} = \beta' x_{in} + \alpha_j' x_n + \varepsilon_{in} \qquad (4.4)$$

where: x_{in} is a matrix of attributes of the alternative i influencing choice by the nth household and ; β is a vector of coefficients for these attributes; x_n is a matrix of individual-specific characteristics of the household that may influence the choice of i; and α_j are vectors of coefficients of the individual-specific characteristic for each of the j alternatives.

To derive a specific operational random utility model (RUM), such as the multinomial logit or conditional logit model, an assumption must be made about the joint probability distribution of the full set of error terms (Ben-Akiva and Lerman, 1985). This is discussed in the next section.

4.4 The multinomial choice model

4.4.1 Overview

The multinomial choice problem deals with the case where a single choice must be made from among two or more alternatives (Greene, 1997), as in this case with choice from four discrete feed technology alternatives. Multinomial discrete choice models have been widely applied in developed countries to studies of travel mode of urban commuters (McFadden, 1974) and valuation of recreation sites (Carson, Hanneman and Wegge, 1989). Similar studies have been applied more recently in developing countries for example, in the valuation of beef carcass attributes by Kenyan butchers (Karugia, 1996) and the valuation of fuelwood collection sites by communal households in Zimbabwe (Hatton MacDonald, 1998).

4.4.2 Specification of the multinomial logit model

Assuming that the random error terms are IID with Weibull density functions and that their difference has a logistic distribution, Mcfadden (1974) has shown that the conditional probability for choice of alternative i is:

$$P_n(i) = \frac{e^{\alpha_i' x_n}}{\sum_{j \in C_n} e^{\alpha_j' x_n}} \qquad (4.7)$$

The choices in our choice set are labeled $0, 1, \ldots, J$ and the estimated equations provide probabilities for the $J + 1$ choices for the decision maker with characteristics x_n giving α_j coefficient vectors of coefficients for each individual specific characteristic (Greene, 1997). Because we define $\alpha_j^* = \alpha_j + q$, meaning that for any vector q the resulting probabilities are identical since terms involving q all drop out, the model is indeterminate. The problem of indeterminacy is solved by normalizing to assume that, for example $\alpha_0 = 0$. Model estimation yields log odds ratios as probabilities of the likelihood of choice of each alternative relative to the normalized alternative (Greene, 1997). Equation 4.8 below describes the logarithm of the likelihood of choosing technology i relative to technology j, the log odds ratio.

$$\log\left(\frac{P_{ni}}{P_{nj}}\right) = x_n'\alpha_{ij},\ j = 0, i = 1, 2, \ldots J \quad (4.8)$$

The α_{ij} in this equation are vectors of the effects of variables in x_n on the likelihood ratio. The model in equation 4.8 implies that we can compute J log odds ratios given our $J+1$ alternatives. The model is estimated by maximum likelihood techniques to generate consistent and efficient estimates of the parameters α_j.

4.4.4 Independence of Irrelevant Alternatives and the nested logit model

The assumption of independence of irrelevant alternatives (IIA) underlies the multinomial logit model. The IIA assumption follows from the assumption that the disturbances are independent and homoskedastic and as such, the log odds ratio of any two alternatives is independent of the utilities of other alternatives (Greene, 1997). This assumption requires that the sources of errors contributing to the disturbances must do so in such a way that the total disturbances are independent, otherwise the MNL will produce incorrect predictions of probabilities (Ben-Akiva and Lerman, 1985).

Chapter 5 – Explanators of Technology Choice: Models and Results

This Chapter begins with a brief outline of the model postulated to explain choice. This is followed by discussion of hypothesized explanatory variables and *a priori* expectations of results. The final section presents and discusses the results of model estimation and results of model simulation.

5.1 Overview

The objective of this study is to explain adoption choices by smallholder dairy farmers faced with trade-offs between two feed sources. These are MPT fodder and purchased concentrates. These two feeds may be adopted in various combinations which are viewed here as comprising a number of discrete feed technology bundles. The discrete feed technology bundles under consideration for adoption and the short names by which these choices are designated in the model are: a) both MPT fodder and concentrates (Both); b) Concentrates alone (Conc); c) MPT fodder alone (MPT); and neither MPT fodder nor concentrates (Neither). The adoption decision is thus analyzed in a multinomial discrete choice framework. From the discussion in Section 4.3 on discrete choice modeling and random utility theory, we assume that a given feed technology bundle *i* will be chosen if the utility gained from choosing *i* is greater than or equal to the utility gained from choosing any other bundle *j*, with some random error.

It is assumed that the indirect utility function can be inferred from choices made by farmers. Consequently, it is hypothesized that the characteristics of the farmers are the explanatory variables of the indirect utility functions and the arguments of the multinomial choice models. Selection of variables that are hypothesized to be associated with feed technology adoption is guided by findings from PRA discussions, theory and the literature as discussed in Chapters 2, 3 and 4. Generally, both economic and socio-economic variables are postulated to influence the feed technology adoption decisions. The variables postulated to explain choice and their summary statistics are presented in Tables 5.1 and 5.2 below for both the wet season and dry season.

Table 5.1: Sample Statistics for Hypothesized Explanatory Variables (n=118)

Variable	*Type*	*Definition*	*Mean*	*S.D.*	*Min*	*Max*
Scale of dairy						
DARYHER	Continuous	Absolute number of dairy cows owned	2.63	2.187	0	12
INMILK	Continuous	Number of dairy cows actually producing milk	1.12	1.15	0	6
Efficiency						
INMDAR	Continuous	Ratio of cows in milk to dairy herd	0.39	0.33	0	1
Cash availability						
DELIVY	Binary	Farmer receiving cash income from dairy	0.356	0.481	0	1
Income source						
MILK1ST	Binary	Dairy considered primary income source	0.42	0.49	0	1
CROP1ST	Binary	Crops considered primary income source				
Land availability						
LANDPRB	Binary	feed problem due to grazing land shortage	0.35	0.48	0	1
MAIZTOT	Continuous	ratio of maize acreage to total land holding	0.410	0.161	0.10	1
Labor availability						
MAIZLAB	Continuous	HH members per acre of maize planted	2.33	1.09	0.5	6
MPT Investment						
MPTAREA	Continuous	year first planted MPT fodder	0.24	0.277	0	2.5
Management						
RECORDY	Binary	farmer keeps records of activities/transactions	0.37	0.48	0	1
LFAY	Binary	farmer attends dairy management meetings	0.46	0.50	0	1
Innovators and experience						
MPT1ST	Continuous	year first planted MPT fodder	1996.9	1.21	1993	1999
JOINDAR	Continuous	year joined dairy association	1993.7	3.71	1984	1999
Gender						
PRDSEXF	Binary	female HH member responsible for dairy	0.65	0.48	0	1
Wealth						
HERDSIZE	Continuous	total number of cattle held (plus non-dairy)	6.085	4.737	0	24
SCOTCHY	Binary	HH owns a scotch cart	0.47	0.50	0	1

Footnote: S.D. = standard deviation; Min = minimum; Max = maximum

Table 5.2: Sample Statistics for Hypothesized Explanatory Variables for the Dry season

Variable	*Type*	*Definition*	*Mean*	*S.D.*	*Min*	*Max*
Scale of dairy						
DARYHER	Continuous	Absolute number of dairy cows owned	2.61	2.10	0	12
INMILK	Continuous	Number of dairy cows actually producing milk	1.15	1.12	0	7
Efficiency						
INMDAR	Continuous	Ratio of cows in milk to dairy herd	0.432	0.329	0	1
Cash availability						
DELIVY	Binary	Farmer receiving cash income from dairy	0.347	0.477	0	1
Wealth						
HERDSIZE	Continuous	Total number of cattle held (including non-dairy)	6.034	4.67	1	15

Footnote: S.D. = standard deviation; Min = minimum; Max = maximum

5.2 Hypothesized Explanatory Variables and a priori Expectations

The *a priori* expectations of the effects of the hypothesized explanatory variables on feed technology choice are summarized in Table 5.3.

5.2.1 Scale of dairy enterprise

The variables DARYHER, indicating the total number of dairy cows, and INMILK, indicating the number of cows currently producing milk, are postulated to represent the scale of the dairy enterprise. In addition to representing the scale of the dairy operations, the presence of milking cows (INMILK) is directly related to milk production for home consumption, marketing to neighbors and delivery to the milk collection center. Therefore, this variable can also be viewed as an indicator of income being received from the dairy. According to Barlett (1984), larger dairy farms are better able to take advantage of productivity-enhancing technology. Although this observation was made in a developed country context, we expect that market oriented smallholder dairy farmers would exhibit the same trend. Thus it is hypothesized that larger dairy enterprises are associated with dairy farmers who may be motivated to use feed technology requiring cash expenditures, as for purchased concentrates, as well as the investment of land, labor, learning, time and effort for MPT fodder.

5.2.2 Productivity - Technical Efficiency

A primary factor thought to influence producers decisions to use a particular feed technology is the productivity or technical efficiency of their dairy herds or enterprises. In general the technological efficiency of dairy herd use is expected to be positively related to adoption of technology. It is hypothesized that adoption of technology will be represented by use of both purchased concentrates and MPT fodder. Zepeda (1994) reports productivity as being significant in explaining the amount of concentrate fed to dairy cattle by milk producers in California. Productivity may reflect human capital as well as physical capital. It can be viewed as a measure of the farmer's management ability and reflects the adoption of particular technologies (Zepeda, 1994). Zepeda (1994) uses the total milk output per cow as a direct measure of productivity. For this study, data on milk output could not be elicited from each respondent due to incomplete records and limitations of the survey period, thus an indirect measure of productivity is proposed. The indirect measure of productivity or technical efficiency that is proposed for this study is the ratio of cows in milk to the total number of dairy cows owned (INMDAR). The ratio INMDAR should reflect successful breeding of cows to induce lactation (which depends on timing of breeding and the breed of cow) and adequate feeding to ensure milk production. This ratio may also be a coping strategy determined by strategic management, by the farmer, of the number of producing cows at any given point in time relative to available feed and other resources. For the purpose of this analysis we assume that the ratio INMDAR is determined solely by the farmer's management, everything else equal. Therefore we hold the effects of cattle breed and farmer opportunistic strategies on the ratio INMDAR constant. The proxy measure is essentially a measure of the technical efficiency of the use of the dairy cow herd in terms of the proportion of the herd that is actually producing milk, relative to the total dairy herd, at a given point in time.

5.2.3 Income sources

The binary variable DELIVY indicates whether or not the farmer is currently receiving cash income from the dairy enterprise. A second binary variable is MILK1ST, the importance stated by the farmer of the dairy enterprise as a source of income. This binary variable is assigned a value of one for farmers who indicated the dairy enterprise as their primary income source and zero otherwise. These variables reflect the hypothesis that if milk income is being generated and is highly valued, this would be an incentive to use feed techniques that require cash outlays or involve relatively high levels of investment of resources (land, labor, time). In a developed country setting, El-osta and Morehart (2000), conclude that specialized dairy farms are more likely to invest in yield-enhancing technologies that are specific to milk production. Assuming that these results would extend to the rational agent in the developing country setting we expect the variables DELIVY and MILK1ST to be negatively related to the use of the specified feed technology 'Neither'. Similarly, the binary variable CROP1ST, which is assigned a value of one for farmers indicating crops as their primary income source, is expected to be negatively related to dairy feed technology bundles that require cash and committed resources.

5.2.4 Management measures

Record keeping may be associated with the desire to collect and analyze information on dairy enterprise activities such as dairy herd status, production output and input use. This information is useful in facilitating efficient management decisions on culling, breeding, tracking costs and revenues (Zepeda, 1994). The variable RECORDY, indicating that a farmer keeps records on the dairy enterprise, is assumed to indicate management ability and progressiveness. Therefore, we expect record keeping to be positively related to the use of feed technologies that may improve production efficiency. Consequently it is expected that record keeping will be negatively related to use of 'Neither' concentrates nor MPT fodder.

The binary variable LFAY, which is given a value of one for farmers that participated in the quarterly Log Framework Analysis (LFA) workshops at the milk collection center, is postulated to indicate industry involvement. Industry involvement may indicate how receptive a farmer is to information and his/her motivation to improve the efficiency of the dairy enterprise. The assumption is that industry involvement reflects the extent to which the farmer seeks out information in the hope of improving efficiency (Rogers and Stanfield, 1968). The purpose of these meetings is to enable the dairy association members and the DDP officers to measure performance of the dairy association as a whole. This is pursued through recording and examining trends in production indicators such as areas grown to fodder crops, number of cows in milk, bulling activity and the quantity and quality of milk delivered to the center by month (ARDA, 1999). A positive response to attending the LFA meetings could indicate a positive inclination towards technology that potentially improves production and efficiency.

5.2.5 Resource constraints

5.2.5.1 Liquidity and credit

Liquidity is reflected in the ability to purchase concentrates. This is directly linked to dairy revenue in particular, since credit is provided to farmers by the milk collection center, whereby concentrates are acquired and the cost of these is deducted from the monthly cheque received as payment for milk delivered to the center. Expenditure on concentrates is thus expected to be directly related to the presence of cows in milk, as Zepeda (1994) observed among California dairy farmers. Consequently, zero expenditure on purchased concentrates may not necessarily indicate a liquidity constraint, but be due to the absence of the need to buy concentrates to feed non-producing cows. In addition, zero expenditure on purchased feeds may reflect substitution away from this cash-requiring feed input, to other livestock feed alternatives. These hypotheses will be tested and assessed by inclusion of the variable DELIVY, indicating whether a farmer is currently receiving dairy income, as an argument in the model. A negative interaction between choice of feed technology incorporating purchased concentrates and DELIVY could indicate substitution away from the purchased feeds or a liquidity constraint.

5.2.5.2 Labor availability

Family size is proposed as a proxy measure for potential labor availability. The wet season is the peak cropping season and the time period when labor demands for the staple maize crop are high. The variable MAIZLAB is a ratio of household size to acres planted to maize. This indicates number of persons potentially available per acre planted to the staple crop. This variable is included as a proxy for wet season labor constraints. Higher values for MAIZLAB will indicate relatively low wet season labor constraints. We expect that labor constrained households will not employ labor-using technologies (Feder, Just and Zilberman, 1985), such as MPT fodder, preferring relatively labor-saving practices, such as purchased concentrates in the wet season. On the other hand, labor constrained farmers may not necessarily use more purchased concentrates or hired labor because of liquidity constraints or if a low value is placed on the dairy enterprise.

5.2.5.3 Land availability

The binary variable LANDPRBY is assigned a value of one for farmers that stated that they faced a feed resource problem because of a shortage of communal grazing land. Inadequate access to communal grazing is expected to be positively related to the use of feed technology alternatives that are potential substitutes to land availability. The variable MAIZTOT, measuring the proportion of total land held by the farmer that is planted to the staple maize crop, is also postulated as a proxy to indicate a land constraint. A higher value of MAIZTOT suggests that the farming household has limited land to allocate to other crops, such as MPT fodder, after satisfying requirements for the maize staple. MAIZTOT is thus expected to be negatively related to use of MPT fodder. Various forms of land constraints have been cited by authors including

Rogers and Stanfield (1968) and Feder, Just and Zilberman (1985) as impediments to technological adoption.

5.2.6 MPT Investment

The area planted to MPT fodder is used as an indicator of the level of investment that farmers have made in production of MPT fodder. The dependent variable is binary and thus indicates whether any MPT fodder was used or not by a farmer, whereas the variable MPTAREA gives an indication of potential extent of use of MPT fodder. The variable MPTAREA is postulated to be particularly important for the dry season since the ability to carry MPT fodder through to the dry season is largely dependent on the farming household's ability to harvest and store excess fodder. Consequently, it is expected that farmers with larger areas planted to MPT fodder are likely to be using this feed source in their dry season feed technology bundle.

5.2.7 Innovation and experience

The variable MPT1ST, indicating the year that the farmer first planted MPT fodder banks, is postulated to reflect the extent to which individual farmers are innovators or early adopters (Rogers and Shoemaker, 1971). Early planting of MPT fodder pastures may also indicate experience, reflecting a previous learning curve for the activity. Experience can be viewed as a form of human capital that results from the investment of time and effort in developing and using a technology. This is generally expected to have a positive effect on adoption (Nelson and Phelps, 1966, Rogers and Shoemaker, 1968; Zepeda, 1994). Another proxy measure of experience is the variable JOINDAR, indicating the year that the farmer joined the dairy association. We expect later dates of MPT planting and later dates when the farmer joined the dairy scheme to be negatively related to a choice of feed technology that incorporates MPT fodder. However, it was observed that the majority of sampled farmers may have undertaken an initial planting of MPT fodder but have since abandoned this crop. Consequently, for such farmers, MPT fodder does not necessarily appear in the chosen feed technology bundle. Thus, a positive relationship between later dates of initial MPT planting and the current use of MPT fodder may also indicate that earlier growers abandoned this technology for some reason.

5.2.8 Wealth and risk management

Wealth is postulated to influence technology adoption (Feder *et al*, 1985). Wealth or profit accumulation is postulated to be measured by the proxy variables HERDSIZE, measuring total number of cattle owned and the binary variable SCOTCHY, which is assigned a value of one if the farmer owns an ox-drawn cart. Cattle and scotch-carts both represent capital investments that arise from accumulated wealth. We expect that relatively wealthy farmers may be able to afford purchased concentrates.

It is possible that wealthy farmers exhibit less risk aversion and are more willing to allocate some land to MPT fodder production. Thus, wealth is expected to be positively related to the use of concentrates and the use of both concentrates and MPT fodder. Wealth or profit accumulation indicators, such as size of cattle herd and scotch cart ownership, may be proxies for the ability to absorb risk. Caveness and Kurtz (1993) showed that in Senegal, wealth and income security were related to farmers' risk perceptions, where farm size and value of production were used as proxy measures of wealth status of farmers. Ability to assess risk, and the opportunities for reducing subjective risks associated with new technology, may also be associated with education, access to information and industry involvement. Therefore, we expect that greater access to information, industry involvement (LFAY) and better education will be positively related to use of the relatively new technology of MPT fodder.

5.2.9 Gender

The gender of the household member responsible for the dairy enterprise is postulated to affect technology choice. The binary variable PRDSEXF, which is assigned a value of one if a female household member is responsible for the dairy enterprise, is a proxy indicator for gender effects on feed technology choice. Women operate under various social and institutional constraints in African agriculture (Muchena, 1994). These may affect the accessibility of land for MPT fodder pasture as well as affecting access to cash or credit to purchase concentrates. We expect that female-headed households may not use concentrates due to cash constraints, favoring MPT fodder that uses land and labor. We also expect that women responsible for the dairy enterprise in male-headed households might not use purchased concentrates if they lack control over allocation of cash. Similarly, they may also not grow MPT fodder because they lack control over allocation of land to the different crop plants. The sign on the estimated coefficient for this variable will, if significant, shed light on these alternate possibilities.

Table 5.3: Expected Direction of Effect of Hypothesized Explanatory Variables

Variable	*Type*	*Survey Definition*	*Expectation for*			
			Both	*Conc*	*Mpt*	*Neither*
Scale of dairy						
DARYHER	Continuous	Absolute number of dairy cows owned	+	+	+/-	-
INMILK	Continuous	Number of dairy cows actually producing milk	+	+	+/-	-
Efficiency						
INMDAR	Continuous	Ratio of cows in milk to dairy herd	+	+	+/-	-
Income source						
MILK1ST	Binary	Dairy considered primary income source	+	+	+/-	-
CROP1ST	Binary	Crops considered primary income source	-	-	+/-	+
Cash availability						
DELIVY	Binary	Farmer receiving cash income from dairy	+	+	-	-
Land availability						
LANDPRB	Binary	Feed problem due to grazing land shortage	+/-	+	-	-
MAIZTOT	Continuous	ratio of maize acreage to total land holding	+/-	+	-	-
Labor availability						
MAIZLAB	Continuous	HH members per acre of maize planted	+	-	+	-
MPT Investment						
MPTAREA	Continuous	Area planted to MPT fodder	+	-	+	-
Management						
RECORDY	Binary	farmer keeps records of activities/transactions	+	+	+/-	-
LFAY	Binary	farmer attended last management meeting	+	+	+/-	-
Innovators and experience						
MPT1ST	Continuous	Year first planted MPT fodder	-	+	-	+
JOINDAR	Continuous	year joined dairy association	-	+	-	+
Gender						
PRDSEXF	Binary	female HH member responsible for dairy	+/-	-	+/-	+/-
Wealth						
HERDSIZE	Continuous	total number of cattle held (plus non-dairy)	+	+	+/-	-
SCOTCHY	Binary	HH owns a scotch cart (ox-drawn cart)	+	+	+/-	-

Footnote: Both = both MPT fodder and purchased concentrates; Conc = purchased concentrates only; MPT = MPT fodder only; Neither = neither MPT fodder nor purchased concentrates used.

5.3 Multinomial logit model specification and results

In the multinomial logit models postulated, technology choice is assumed to be dependent on a set of individual-specific (respondent-specific) variables. The models and results for wet and dry seasons are considered separately because of the effect on feed technology choice of seasonal factors as discussed in Section 3.4.2. These factors include seasonal variation in the qualitative and quantitative availability of the various feeds, scale of dairy enterprise, efficiency of use of dairy herd and resource availability, all of which are expected to influence choice of feed technology.

For estimation of the multinomial logit model in the log odds ratio form as presented in equation 4.8 (Section 4.4.3), a reference choice category is assumed. The 'Neither' technology bundle reflecting the decision of no technological adoption is assumed as the reference technology in this case. The estimated coefficients α_j for all j $(j=1,\ldots\ldots J)$, after normalizing the 'Neither' alternative $j=0$, measure the effect of the explanatory variables in the indirect utility function on the likelihood of choosing technology i relative to the 'neither' option j.

5.3.1 Wet season MNL models specification and results

The indirect utility (V_{in}) function for an individual household n of a feed technology alternative is specified as follows for the wet season.

Model **W1** for wet season feed technology choice:

$$\begin{aligned} V_{in} = {} & \alpha_{0i} + \alpha_{1i}INMDAR + \alpha_{2i}MPT1ST + \alpha_{3i}CROP1ST + \alpha_{4i}JOINDAR + \alpha_{5i}HERDF \\ & + \alpha_{6i}MAIZTOT + \alpha_{7i}LANDPRB + \alpha_{8i}DARYHER + \alpha_{9i}INMILK + \alpha_{10i}DELIVY + \\ & \alpha_{11i}MAIZLAB + \alpha_{12i}MPTAREA + \alpha_{13i}RECORDY + \alpha_{14i}LFAY + \alpha_{15i}PRDSEXF \\ & + \alpha_{16i}SCOTCHY + \varepsilon_{in} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.1) \end{aligned}$$

where, α_i denote vectors of coefficients of the explanatory variables for each of the i feed technology bundles $(i=1,2,\ldots,4)$.

The MNL Model W1 tested on the data for the wet season was estimated using maximum likelihood methods using the econometrics software Limdep Version 7.0 (Greene, 1994). The variable MILK1ST is not included in this model because initial analysis revealed that this variable exactly identified the dependent variable, thus causing problems of collinearity. The estimated results for Model W1 are presented in Appendix I. The model results indicate 75.4% correct predictions, an R-square of 0.50 and a likelihood function of –68.18. However, only seven of the estimated coefficients on the sixteen variables are significant at the 90 percent significance level. The significant variables are INMDAR, CROP1ST, MPTAREA, MAIZLAB, SCOTCHY, LANDPRB, MPT1ST. Consequently, a reduced version of Model W1 was assessed for wet season feed technology choice with seven variables found to be significant in the assessment of Model W1. The objective is to investigate the effects of these variables and whether there may be any difference in the magnitude of estimates or in model explanatory power.

The reduced MNL model version, Model **W2** for wet season feed technology choices is specified as follows:

$$\begin{aligned} V_{in} = {} & \alpha_{0i} + \alpha_{1i}MPT1ST + \alpha_{2i}CROP1ST + \alpha_{3i}INMDAR + \alpha_{4i}LANDPRB \\ & + \alpha_{5i}MAIZLAB + \alpha_{6i}MPTAREA + \alpha_{7i}SCOTCHY + \varepsilon_{in} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.2) \end{aligned}$$

An additional reduced version, MNL Model W3 is analyzed from variables found significant in model W2 as a means to assess the sensitivity or robustness of the estimates.

Model **W3** for wet season feed technology choice is specified as follows:

$$\begin{aligned} V_{in} = {} & \alpha_{0i} + \alpha_{1i}MPT1ST + \alpha_{2i}CROP1ST + \alpha_{3i}INMDAR + \alpha_{4i}LANDPRB \\ & + \alpha_{5ii}MPTAREA + \varepsilon_{in} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.3) \end{aligned}$$

Models W2 and W3 were estimated by maximum likelihood methods using the econometrics software Limdep Version 7.0 (Greene, 1994). The results of the estimation of these models, giving the choice probabilities at the means, the estimated coefficients, and the t-statistics, for the Models W2 and W3 are presented in Table 5.4a below. The marginal effects, calculated as partial derivatives of the utility functions for choice of each feed technology, are generated by Limdep and are presented in Table 5.4b below.

Table 5.4a: Estimated coefficients for MNL wet season feed technology choice

	Model W2				Model W3			
Variable	*Both N=67*	*Conc n=20*	*Mpt n=13*	*Neith n=18*	*Both N=67*	*Conc n=20*	*Mpt n=13*	*Neith n=18*
Choice probabilities	0.769	0.087	0.087	0.057	0.745	0.095	0.091	0.069
CONSTANT	5.615	-3.314	5.970		3.660	-5.174	4.007	
	(2.385) b	(-1.168)	(2.305)b		(1.872)c	(-2.18)b	(1.875)c	
MPT1ST	-1.030	0.815	-1.095		-1.04	0.863	-1.158	
	(-2.362) b	(1.740) c	(-2.234)b		(-2.444)b	(1.927)c	(-2.434)b	
CROP1ST	-2.800	-2.736	-2.619		-2.05	-1.946	-2.063	
	(-2.755)a	(-1.914)c	(-2.197)b		(-2.424)b	(-1.582)	(-1.933)c	
INMDAR	3.083	4.400	-1.167		2.828	4.100	-1.552	
	(2.078)b	(2.671)a	(-0.608)		(2.035)b	(2.655)a	(-0.826)	
LANDPRB	1.274	-0.573	1.034		1.528	-0.157	1.191	
	(1.243)	(-0.492)	(0.863)		(1.597)	(-0.145)	(1.053)	
MAIZLAB	-0.526	-0.299	-0.822					
	(-1.479)	(-0.760)	(-1.699)c					
MPTAREA	6.229	4.556	5.687		5.942	3.714	5.201	
	(2.292)b	(1.583)	(1.898)c		(2.251)b	(1.334)	(1.798)c	
SCOTCHY	-1.121	-1.960	-0.576					
	(-1.378)	(-2.077)b	(-0.602)					
Correct Prediction	94.0%	65%	7.7%	55.5%	92.5%	65%	0%	55.5%
Model	73.7%				72.0%			
Log likelihood	-85.329				-89.332			
LR test Chi-sq.	101.22 (21df)				93.22 (15 df)			
Model R-square	0.372				0.343			

Footnotes: t-statistics in parentheses; a = significant at 99%; b = significant at 95%; c = significant at 90% level

Table 5.4b: Estimated marginal effects for MNL wet season feed technology choice

	Model W2				Model W3			
Variable	*Both N=67*	*Conc n=20*	*Mpt n=13*	*Neith n=18*	*Both N=67*	*Conc n=20*	*Mpt n=13*	*Neith n=18*
CONSTANT	0.821	-0.687	0.124	-0.259	0.791	-0.741	0.128	-0.178
	(3.093)a	(-3.192)a	(0.992)	(-1.717)c	(3.357)a	(-3.767)a	(1.208)	(-1.320)
MPT1ST	-0.164	0.142	-0.024	0.046	-0.181	0.159	-0.032	0.055
	(-2.887)a	(3.091)a	(-0.998)	(1.561)	(-3.137)a	(3.420)a	(-1.368)	(1.675)c
CROP1ST	-0.139	-0.010	0.000	0.149	-0.111	-0.004	-0.015	0.130
	(-0.982)	(-0.101)	(0.999)	(2.039)b	(-0.783)	(-0.042)	(-0.189)	(1.950)b
INMDAR	0.331	0.153	-0.333	-0.151	0.351	0.166	-0.355	-0.162
	(1.999)b	(1.665)c	(-2.919)a	(-1.696)c	(2.114)b	(1.755)c	(-3.274)a	(-1.716)c
LANDPRB	0.196	-0.139	0.001	-0.058	0.221	-0.132	-0.004	-0.084
	(1.860)c	(-1.983)b	(0.020)	(-1.116)	(2.079)b	(-1.907)c	(-0.058)	(-1.439)
MAIZLAB	-0.018	0.018	-0.028	0.029				
	(-0.431)	(0.736)	(-0.927)	(1.406)				
MPTAREA	0.421	-0.098	0.001	-0.323	0.512	-0.147	-0.005	-0.361
	(1.751)c	(-0.727)	(0.004)	(-1.813)c	(2.068)b	(-1.032)	(-0.036)	(-2.01)b
SCOTCHY	-0.029	-0.077	0.044	0.062				
	(-0.321)	(-1.368)	(0.793)	(1.372)				

Footnotes: t-statistics in parentheses; a = significant at 99%; b = significant at 95%; c = significant at 90% level

5.3.2 Dry Season MNL Model Specification and Results

The indirect utility (V_{in}) function, to an individual household *n* of feed technology alternatives $I=1,\ldots 4$ is specified as follows for the dry season.

Model **D:1** for dry season feed technology choice:

$$
\begin{aligned}
V_{in} = {} & a_{0i} + a_{1i}INMDAR + a_{2i}MPT1ST + a_{3i}CROP1ST + a_{4i}JOINDAR + a_{5i}HERDF \\
& + a_{6i}MAIZTOT + a_{7i}LANDPRB + a_{8i}DARYHER + a_{9i}INMILK + a_{10i}DELIVY \\
& + a_{11i}MPTAREA + a_{12i}RECORDY + a_{13i}PRDSEXF + a_{14i}SCOTCHY \\
& + \varepsilon_{in} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.4)
\end{aligned}
$$

where α_i denote vectors of coefficients of the explanatory variables for each of the *i* feed technology bundles.

The MNL model D1 was estimated using maximum likelihood methods using the econometrics software Limdep Version 7.0 (Greene, 1994). The variables MILK1ST and LFAY are not included in this model because of the problem of collinearity with the inclusion of variable MILK1ST and the problem of singularity with inclusion of LFAY. The variable MAIZLAB is not included in the dry season model as this is an indicator of labor availability in the wet season, which is the peak cropping season.

The estimated results for Model D1 are presented in Appendix B. The model results indicate 73.7% correct predictions, an R-square of 0.56, and a log likelihood function of –62.25. Only two variable marginal effects were significant at 90 percent level or better. Therefore, using a cut-off point of 80 percent significance level the following seven variables were found significant: INMILK, CROP1ST, MPT1ST, MPTAREA, HERDF, DARYHER and RECORDY. These variables found significant at the 80 percent level in Model D1 are then postulated in a reduced Model D2 that is then assessed for dry season feed technology choice. The objective is to investigate the effects of these variables and whether there may be any difference in the magnitude of estimates or in model explanatory power.

Model **D2** for dry season feed technology choice is specified as follows:

$$
\begin{aligned}
V_{in} = {} & a_{0i} + a_{1i}INMILK + a_{2i}CROP1ST + a_{3i}MPT1ST + a_{4i}MPTAREA \\
& + a_{5i}HERDF + a_{6i}DARYHER + a_{7i}RECORDY + \varepsilon_{in} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5.5)
\end{aligned}
$$

Another reduced MNL model version Model D3, is specified and analyzed from variables found to have significant marginal effects in Model D2 for dry season feed technology choice. This enables assessment of the sensitivity or robustness of the estimated coefficients.

The specification of Model **D3** for dry season feed choice is as follows;

$$V_{in} = \alpha_{0i} + \alpha_{1i}INMILK + \alpha_{2i}CROP1ST + \alpha_{3i}MPT1ST + \alpha_{4i}MPTAREA$$
$$+ \alpha_{5i}DARYHER + \varepsilon_{in} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5.6)$$

Models D2 and D3 were estimated by maximum likelihood methods using the econometrics software Limdep Version 7.0 (Greene, 1994). The results of the estimation of these models, giving the choice probabilities at the means, the estimated coefficients, and the t-statistics, for the Models D2 and D3 are presented in Table 5.5a below.

Table 5.5a: Estimated coefficients for MNL dry season feed technology choice

	Model W2				*Model W3*			
Variable	*Both n=58*	*Conc n=33*	*Mpt n=12*	*Neith n=15*	*Both n=58*	*Conc N=33*	*Mpt n=12*	*Neith n=15*
Choice probabilities	0.768	0.221	0.009	0.002	0.739	0.232	0.021	0.007
CONSTANT	-0.125	-5.920	3.939		1.021	-4.532	2.542	
	(-0.046)	(-1.997)**b**	(1.178)		(0.469)	(-1.913)**c**	(1.107)	
INMILK	1.805	3.386	-0.371		2.310	3.804	-0.245	
	(1.735)**c**	(3.136)**a**	(-0.277)		(2.246)**b**	(3.507)**a**	(-0.186)	
CROP1ST	-3.489	-5.917	-4.806		-2.181	-4.125	-2.669	
	(-2.575)**a**	(-3.090)**a**	(-2.620)**a**		(-2.178)**b**	(-2.832)**a**	(-2.186)**b**	
MPT1ST	-0.711	0.609	-1.179		-0.673	0.571	-0.869	
	(-1.434)	(1.193)	(-2.012)**b**		(-1.582)	(1.356)	(-1.776)**c**	
MPTAREA	8.460	3.584	9.024		8.420	4.034	9.797	
	(2.200)**b**	(0.894)	(2.289)**b**		(2.289)**b**	(1.042)	(2.625)**a**	
HERDF	2.425	2.671	-1.920					
	(1.486)	(1.548)	(-0.661)					
DARYHER	0.997	0.631	0.339		0.684	0.374	0.096	
	(1.471)	(0.916)	(0.418)		(1.288)	(0.684)	(0.157)	
RECORDY	2.737	2.607	3.461					
	(1.625)	(1.511)	(0.052)					
Correct Prediction	81.0%	57.6%	66.7%	55.5%	81.0%	51.5%	50.0%	80.0%
Model	71.2%				69.5%			
Log likelihood	-76.77.3				-82.236			
LR test Chi-sq.	129.67 (21df)				118.75 (15 df)			
Model R-square	0.458				0.419			

Footnotes: t-statistics in parentheses; a = significant at 99%; b = significant at 95%; c = significant at 90% level

The marginal effects, calculated as partial derivatives of the utility functions for choice of each feed technology, are generated by Limdep and are presented in Table 5.5b below.

Table 5.5b: Estimated marginal effects for MNL dry season feed technology choice

	Model W2				*Model W3*			
Variable	***Both n=58***	***Conc n=33***	***Mpt n=12***	***Neith n=15***	***Both n=58***	***Conc n=33***	***Mpt n=12***	***Neith n=15***
CONSTANT	0.957	-1.006	0.046	0.003	0.936	-0.996	0.059	0.018
	(3.563)a	(-3.785)a	(0.967)	(0.421)	(3.522)a	(-3.834)a	(1.035)	(0.117)
INMILK	-0.251	0.277	-0.021	-0.005	-0.204	0.283	-0.060	-0.019
	(-2.784)a	(3.171)a	(-0.847)	(-0.635)	(-2.157)b	(3.227)a	(-1.484)	(-0.964)
CROP1ST	0.415	-0.417	-0.007	0.009	0.330	-0.348	-0.001	0.019
	(1.940)b	(-1.953)c	(-0.590)	(0.668)	(1.594)	(-1.674)c	(-0.037)	(0.867)
MPT1ST	-0.222	0.228	-0.006	0.001	-0.214	0.222	-0.010	0.003
	(-3.546)a	(3.661)a	(-0.867)	(0.543)	(-3.413)a	(3.621)a	(-0.899)	(0.678)
MPTAREA	0.839	-0.837	0.014	-0.016	0.778	-0.775	0.051	-0.054
	(2.567)b	(-2.545)b	(0.703)	(-0.641)	(2.419)b	(-2.40)b	(1.265)	(-0.863)
HERDF	-0.009	0.052	-0.037	-0.005				
	(-0.076)	(0.456)	(-1.084)	(-0.640)				
DARYHER	0.068	-0.061	-0.005	-0.002	0.066	-0.051	-0.011	-0.004
	(1.743)c	(-1.581)	(-0.826)	(0.474)	(1.734)c	(-1.387)	(-0.942)	(0.413)
RECORDY	0.022	-0.022	0.006	-0.006				
	(0.213)	(-0.218)	(0.642)	(0.487)				

Footnotes: t-statistics in parentheses; a = significant at 99%; b = significant at 95%; c = significant at 90% level

5.4 Discussion of Results

5.4.1 Choice probabilities for the wet and dry season feed technology choice

In general, both Model W2, tested on wet season data and Model D2, tested on dry season data, perform reasonably well (see Tables 5.4a and 5.5a). Correct predictions for the wet season Model W2 are 73.7 percent and for the dry season Model D2, correct predictions are 71.2 percent. The likelihood ratio test statistic for the overall significance of coefficients in explaining choice is significant for both the wet and dry season. Model R-squares are above 0.37, which is high for this type of model.

The results from Model W2 and D2 show that both MPT fodder and purchased concentrates (the 'Both' technology bundle) are most likely to be used in both the wet and dry season. The probability of choice of the 'Both' technology is just over 76 percent for both seasons. This indicates that MPT fodder and purchased concentrates are more likely to be used as complements rather than having become substitutes. During the dry season a markedly higher probability of using purchased concentrates alone (the 'Conc' technology alternative) is observed. This is 22.1

percent, compared to 8.7 percent in the wet season. This result is consistent with the general expectation of reduced use of purchased concentrates in the wet season, due to the availability of natural plant-based feeds in that season. These are from communal grazing and woodland areas, grass and legume pastures as well as MPT fodder pastures. The qualitative and quantitative availability of these forages and of browse increases significantly with the rains. The probability of use of 'MPT alone' is higher in the wet season, at 8.7 percent, compared to a probability of choice of 0.9 percent in the dry season. The reduced probability of use of MPT alone in the dry season may reflect the fact that new MPT fodder leaves are constantly growing in the rainy season resulting in increased browse availability during the wet season. In contrast, dry season access to MPT fodder largely depends on storage of surplus from the wet season since there is limited leaf growth once rains have stopped. The probability of using neither MPT fodder nor purchased concentrates (the 'Neither' alternative) is higher in the wet season, at 5.7 percent, compared to 0.2 percent in the dry season. This could be associated reduced activity in the dairy enterprise during the peak cropping period (wet season) when cropping activity may be more highly valued and when labor demands for crops are highest.

5.4.2 Estimated coefficients and marginal effects for the wet and dry seasons

A positive and significant estimated coefficient implies that the values of the explanatory variables that are observed in the sample are positively associated with choice of the feed technology category, relative to the choice of the category 'Neither'. The estimated marginal effects indicate the effect of a unit change in the value of a given explanatory variable on the choice probability of each technology bundle. The results depict heterogeneity across feed technology adoption categories and by season. That is, the explanatory variables have a different effect on probability of choice for each feed technology alternative and also in each season. In general, the estimated coefficients and the calculated marginal effects are consistent with the expectations for both the wet season and the dry season as outlined in Section 5.2.

The ratio of cows actually producing milk to the total number of dairy cows owned (INMDAR), was postulated as an indicator of productivity or technical efficiency of the dairy operator. INMDAR is significant and positively associated with use of both MPT fodder and purchased concentrates (category 'Both') and with use of purchased concentrates alone ('Conc'), relative to using neither of these in the wet season (see results of Model W2 in Tables 5.4a and b). The marginal effect of the ratio INMDAR on choice is significant and positive for the categories 'Both' and 'Conc' and significant and negative on choice of 'MPT' alone and the category

'Neither'. Thus the ratio of currently producing cows is significantly and positively associated with the purchase of concentrates as feeds. This is as expected, as discussed in Section 5.2, since the presence of milk producing cows implies that income is being generated. This source of income may be associated with liquidity and access to credit as well as with willingness to incur cash expenditures on dairy feeds. The negative and significant marginal effect for choice of MPT fodder alone (MPT) suggests that technical efficiency or dairy enterprise productivity is not associated with use of MPT fodder alone, but that this is seen in combination with purchased concentrates.

As indicated in Table 5.5a for the dry season, the absolute number of cows producing milk (INMILK), is significant and positively related to the choice of both MPT fodder and purchased concentrates (Both) as well as being positively related to choice of purchased concentrates (Conc) alone. The presence of milk producing cows provides income that contributes to liquidity and may induce increased cash expenditure on dairy feeds with the prospects of greater returns from milk production. The coefficient on the total number of dairy cows owned (DARYHER), is insignificant in explaining choice, but the marginal effect of the total number of dairy cows owned (DARYHER) is significant and positively related to use of the category 'Both' (Table 5.5b). The marginal effect of the number of cows producing milk (INMILK) is significant and negatively related to use of 'Both', suggesting that even though a larger scale of dairy enterprise induces use of 'Both', a greater number of cows producing milk does not. The positive significant effect of the number of producing cows on the choice of purchased concentrates alone (Conc) reinforces this observation, by indicating that an increase in the number of producing cows will induce use of 'Conc'. This can be explained by the income generation associated with cows producing milk which warrants expenditures on commercial feeds for milking cows to increase revenue.

The pattern observed in the estimated coefficients and marginal effects for INMDAR, INMILK and DARYHER is as expected since the ability to employ the cash requiring purchased concentrates may be directly related to income generation from milk produced. Similarly, Zepeda (1994) reports dairy cow productivity as being significant in explaining the amount of concentrate fed to dairy cattle by milk producers in California. The effects of INMILK and DARYHER on the choice of MPT fodder alone (MPT) are insignificant, suggesting that MPT fodder alone may be a feed resource used, regardless of productivity, as a dairy animal maintenance feed.

From the discussion in Section 3.4 of the dairy cow feed requirements and overview of actual feeding practices by Chikwaka farmers, it appears that purchased concentrates and MPT fodder are used as the sources of dietary crude protein (CP). This is because the main challenge in provision of adequate feed is in meeting the animal's dietary requirements for crude protein (CP) and the two feeds, MPT fodder trees and purchased concentrates are the only reliable sources for adequate levels of crude protein (CP). This suggests an expectation that farmers would use MPT fodder as the main source of CP in dairy animals' diet thus saving cash expenditures on purchased feeds. However, for those farmers growing MPT fodder trees, there appear to be limitations to such use because of limited total MPT fodder output, as determined by area planted and yields as determined by agronomic and management constraints and experience with growing the trees. This could explain the observed results that technically efficient farmers are more likely to use purchased concentrates alone or to use both purchased concentrates and MPT fodder in their feed technology bundle, as opposed to using MPT fodder alone which arguably may be higher quality feed in terms of crude protein content. Dry season use of MPT fodder may be further limited by the reduced CP content of dried fodder, compared to fresh fodder in the wet season.

Farmers who indicated that their field crops are their primary income source are less likely to choose any of the three technology bundles relative to the 'Neither' option. The variable CROP1ST, indicating that crop income is the primary source of cash income, is significant and negatively related to choice of all dairy cattle feed technology bundles for both the wet and dry seasons. This variable accords with expectations, based on the reasoning that more specialized dairy production farm, are more likely to use investments to obtain yield-enhancing technologies that are specific to milk production (El-Osta and Morehart, 2000), whereas this was not expected for crop-specialized farms. Thus the nature of farm specialization or profit expectation from crops may play important roles in use of feed technology bundles incorporating MPT fodder and/or purchased concentrates. From the dry season model results, the marginal effect of changing from a situation where crops are the primary cash income source, to a situation where crops are not the primary cash income source, is to increase significantly the probability of using both MPT fodder and purchased concentrates. This suggests that if crops are a secondary source of income, there is motivation for increased expenditure of cash and other resources, such as land and labor, on the dairy enterprise. The change in importance of crop income however, is significant and negatively related to use of purchased concentrates alone, suggesting that specialization in dairy yield-enhancing technology does not necessarily follow. The marginal effect of a change from crops as the primary income source are insignificant for the wet season model. This may possibly reflect the feature that this is the peak cropping period when crop income is for-seeable as compared to the dry season.

Farmers that started planting MPT fodder trees in later years are less likely to use both MPT fodder and purchased concentrates (Both) and these farmers are also less likely to use MPT fodder alone (MPT), as shown by the significant negative estimated coefficients on the variable MPT1ST. Conversely, MPT1ST is positively related to the use of 'Conc' alone, relative to the category 'Neither'. This observation is true for both the wet and the dry season models. An earlier date for the first planting of MPT fodder may suggest experience acquired with this relatively new technology, available since 1994, which may reflect a learning curve. We assume therefore that earlier first planting furnishes the farmer with greater human capital in the form of experience from the time and effort invested in developing and using the MPT fodder technology (Nelson and Phelps, 1966). This experience is expected to affect the ability to harvest MPT fodder for use in the wet season, and on the ability to carry-over excess MPT fodder to store for use in the dry season. The marginal effects of increasing the year of first planting (in other words, the marginal effect of reducing the years of experience with MPT fodder trees by a farmer) yields similar conclusions. The probability of using MPT fodder decreases with less experience and the probability of using purchased concentrates increases with less experience with growing the fodder trees. The results are consistent with expectations for both the wet and dry season models, since it is apparent from the results that less experienced farmers will not use MPT fodder and will use purchased concentrates.

As discussed in Section 3.4, on-station research by Dzowela (1997) on MPT fodder shows that factors like timing of cutting of fodder trees for harvest affects yields and re-growth in the dry season. Such information may probably only be obtained and utilized by the individual farmer after years of experience with growing and harvesting the MPT fodder, thus illustrating the importance of experience. Dissemination of the results of on-station research is, however important, in bridging the learning curve gap.

The area planted to MPT fodder, measured by the variable MPTAREA, reflects the level of investment in MPT fodder trees. The area planted to MPT is positively and significantly related to choice of all technology bundles incorporating MPT fodder, (that is, the 'Both' and the 'MPT' categories), relative to the category 'Neither'. The marginal effect of an increase in the area planted to MPT fodder is to increase the probability of using both MPT fodder and purchased concentrates (Both) and to reduce the probability of using 'Neither' significantly in the wet season (Model W2). In the dry season Model D2, increasing the MPTAREA significantly increases the probability of using both MPT fodder and purchased concentrates (Both). This increase in MPT area also reduces the probability of choosing purchased concentrates alone (Conc). The significant negative marginal effect of increased MPTAREA on the probability of choosing 'Conc' suggests that greater areas planted to MPT fodder may substitute for the use of purchased concentrates.

These results are consistent with expectations since the ability to use MPT fodder in both the wet and the dry season is directly linked to fodder outputs, for which area planted may be considered a proxy. The calculated mean area planted to MPT fodder trees by farmers in this sample is 0.248 acres (0.105 hectares). Average yields of 0.93 tons per hectare were observed, for all MPT species grown, among eight farmers who participated in on-farm trials with ICRAF in Chikwaka since 1994 (Burgers, Dzowela and Franzel, 1997). Applying the calculations of Burgers *et al* (1997), as outlined in Section 3.4.2.5, for the farmers in this sample with an average of 0.105 hectares MPTAREA, MPT fodder yields would be expected to provide supplementation for one dairy cow for about 33 days only. Thus it is not surprising that MPT fodder output may be insufficient to substitute for the use of purchased concentrates as a high protein feed. For this to be the case, area planted would need to be expanded or higher yielding species grown along with improved management.

The dummy variable LANDPRB, indicating a grazing land constraint, is hypothesized to explain wet season feed technology choice (Model W2). The marginal effect measures the effect on choice probabilities of changing from a situation where a grazing land constraint is cited to one where grazing land is not a constraint. The results show that the absence of a grazing land constraint results in a significantly reduced probability of using purchased concentrates alone. This is likely because purchased concentrates are used as a feed resource to substitute for shortage of grazing. The marginal effect is also significant in increasing the probability of using both MPT fodder and purchased concentrates. This is an unexpected result since use of these alternatives is postulated to substitute for the shortage of grazing land as a feed resource.

The postulated wealth indicators are the total number of cattle owned (HERDF), for Model D2 tested on dry season data, and the ownership of an ox-drawn scotch-cart (SCOTCHY) for Model

W2 which is tested on wet season data. HERDF is insignificant in explaining choice of feed technology in the dry season. This is in contrast to expectations that wealth would be positively related to use of investment requiring feed sources such as purchased concentrates requiring cash and MPT fodder requiring land and labor. HERDSIZE is, however, insignificant in explaining wet season feed technology choice). The marginal effect of SCOTCHY on the probability of choosing purchased concentrates alone is insignificant.

Management ability as measured by the variable RECORDY, indicating that the farmer keeps records on the dairy enterprise, is insignificant in explaining dry season feed technology choice. This contradicts expectations since we had expected that farmers exhibiting management ability, reflected in record keeping, may be motivated to collect and analyze information on the dairy enterprise with the aim of facilitating efficient decisions, and that this motivation could be reflected in the choice feed technology.

The ratio of household size to area planted to the staple maize crop (MAIZLAB in people per acre) was postulated as a relative indicator of wet season labor availability. The higher the value of MAIZLAB, the greater the number of people a given farming household has potentially available to work per acre of maize crop. The results in Table 5.4a for model W2 tested on data for the wet season indicate, with statistical significance, that higher labor availability is negatively related to choice of the feed technology category 'Neither', where neither MPT fodder nor purchased concentrates are used. This result is consistent with expectations. However, the marginal effect of an increase in MAIZLAB is insignificant.

5.4.3 Sensitivity and robustness of estimates for both the wet and dry seasons

The objective of estimating reduced models is to assess the robustness of the estimates for variables found to be significant explanators for wet and dry season choice. The reduced model thus provides a sensitivity test for the estimates.

The reduced models perform well, with correct predictions above 69%, R-squared above 0.34 and significant likelihood ratio test statistics. The estimated coefficients and marginal effect estimates are again significant and have the same signs and similar magnitudes to the results observed in Model W2 for wet season and Model D2 for the dry season. These estimates suggest that the postulated models are robust.

5.5 Model simulation and results

Following the approach of El-Osta and Morehart (2000), calculated means of the explanatory variables and the estimated coefficients of the multinomial logit models are used to simulate the effect of changes in the continuous variables (INMDAR, INMILK, MPT1ST and MPTAREA) on the probability of choice of each feed technology bundle. The indirect utility functions are calculated using equation 5.2 for Model W2, tested on data for the wet season and equation 5.5 for Model D2, tested on data for the dry season. Figures 5.1 (a to c) to 5.2 (a to c) below present simulated probability results for the wet season and the dry season feed technology choices respectively.

Simulating changes in the variable INMDAR indicates the effects on the probability of choosing a given feed technology bundle, of changes in the ratio of cows actually producing milk to the total dairy herd. A change in the value of INMDAR reflects changes in efficiency, with the upper limit being a ratio of one, when all dairy cows owned are producing milk. The variable INMDAR is included in the indirect utility function for feed technology choice in the wet season and is thus simulated for this season only. The calculated sample mean for the ratio INMDAR is 0.39. Values of INMDAR used for simulation range from zero to one. For the dry season, changes in the variable INMILK, which measures the absolute number of dairy cows that are producing milk, are used to simulate the effect of an increase in the absolute number of producing cows on feed technology choice. The variable INMILK is in the dry season utility function for feed technology choice. The calculated sample mean for INMILK is 1.178. Values of INMILK used in simulation range from zero to three cows.

The variable MPT1ST indicates the year in which farmers undertook initial planting of MPT fodder trees. Simulation of this variable is expected to indicate the effect of experience in planting MPT fodder on probability of choosing each feed technology bundle. We expect that more years of experience, reflected in early planting dates, may result in higher probabilities of using MPT fodder. The sample mean for MPT1ST is the 1996.88 indicating less than 2.5 years experience in planting MPT fodder by the time of the survey in late 1999. Values for MPT1ST used in simulation range from the year 1985 to 1999, indicating 14 years and less than one year of experience respectively.

MPTAREA indicates the acreage planted to the MPT fodder trees and hence the potential output of MPT fodder. Larger areas planted to MPT fodder may be associated with greater access to this feed particularly in the dry season when use of this feed is largely dependent on storage of wet season surplus. Therefore, simulating the variable MPTAREA indicates the effect of MPT pasture area expansion on the probability of choosing each feed technology bundle. The calculated sample mean for MPTAREA is 0.248 acres and the values used in simulation range from zero to one 0.5 acres.

5.5.1 Results of Simulated Choice Probabilities for the Wet Season

From Figure 5.1a, we observe that the probability of using both MPT fodder and purchased concentrates remains above 70 percent for a ratio of cows producing milk to the total dairy herd (INMDAR) that is between zero and 0.4. The probability of using MPT fodder alone remains below 10 percent and falls to approach zero for a ratio of producing cows (INMDAR) that is above 0.7. The probability of using purchased concentrates remains below 30 percent until a ratio of INMDAR of about 0.45 applies when the probability rises sharply to overtake the probability of using 'Both', at an INMDAR ratio of about 0.53. This suggests that the use of purchased concentrates alone is compatible with high levels of technical

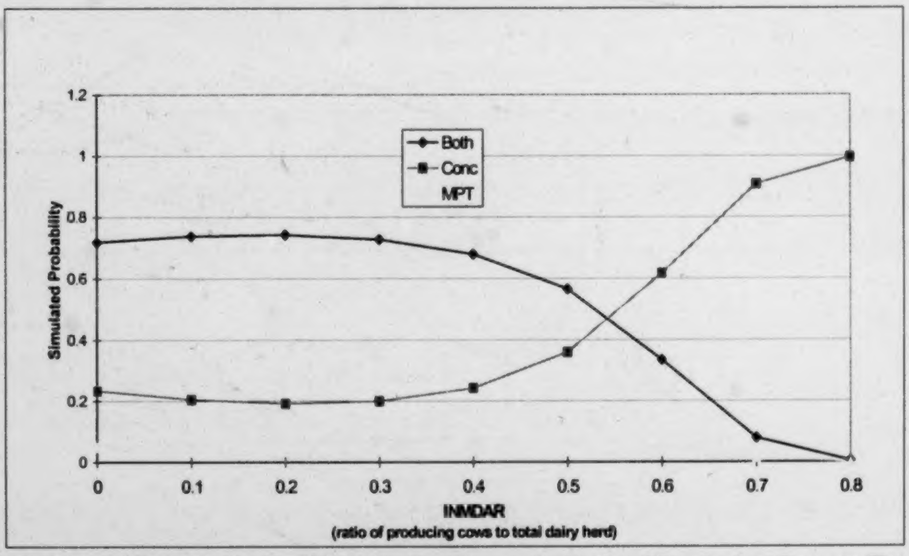

Fig 5.1a: Simulated Choice Probabilities for Change in Ratio of Producing Cows to Total Herd (Wet Season)

efficiency in the dairy enterprise (as measured by the ratio INMDAR of milk producing cows to non-producing cows), likely because milk revenue is concomitantly higher providing cash to purchase concentrates. Use of both MPT fodder and purchased concentrates occurs with dairy enterprise technical efficiency below 55 percent possibly because revenue received from milk may not justify reliance on purchased concentrates alone. The generally low probability of using MPT fodder at high levels of technical efficiency may be due to limited quantities available, hence an inability to satisfy dietary crude protein requirements of a larger milking herd.

Reference to Figure 5.1b suggests that there is a drop-off from the year 1995, as the year of first planting MPT fodder, where the probability of using both MPT fodder and purchased concentrates and MPT fodder alone begins to fall. First planting in 1995 indicates about four years experience with MPT fodder trees and the simulation results show that farmers with less than four years experience with MPT fodder planting have a lower probability of choosing the feed technology bundles incorporating MPT fodder. At the planting date of 1998, the probability of using purchased concentrates alone overtakes the probability of using both MPT fodder and purchased concentrates. .

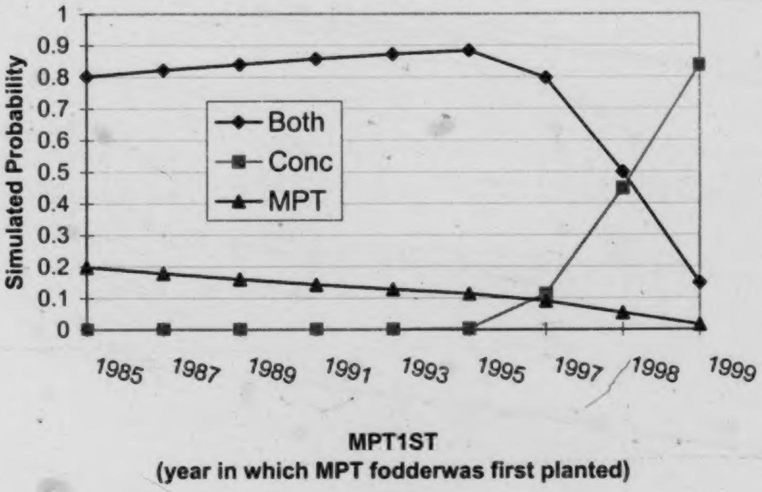

Fig 5.1b: Simulated Choice Probabilities for Change in Year in which MPT fodder was First Planted (Wet Season)

This peaks at about 85 percent for first planting in 1999 when the survey was conducted. The sample mean of 1996.88 as the year of first planting of MPT fodder indicates less than 2.5 years of experience with MPT fodder planting on average. The simulated probabilities for first planting in 1985, indicating about 14 years of experience with MPT fodder planting, show that the probability of using MPT fodder alone reaches a peak of about 20 percent, whilst the probability of using both MPT fodder and purchased concentrates peaks at 80 percent. This suggests that use of MPT fodder and purchased concentrates in the wet season is complementary regardless of the number of years of experience with MPT fodder planting. This follows from the fact that availability of MPT fodder is almost guaranteed in the wet season when the rains begin, as long as MPT fodder trees have been planted.

The results shown in Figure 5.1c reinforce the observation of complementary use of both MPT fodder and purchased concentrates in the wet season suggested above and in Section 5.5. The probability of using both MPT fodder and purchased concentrates is above 76 percent and this increases steadily at all levels of area planted to MPT fodder (MPTAREA) from zero to 0.5 acres. An increase in area planted to MPT fodder slightly reduces the probability of using purchased concentrates alone whilst simultaneously slightly increasing the probability of using MPT fodder alone.

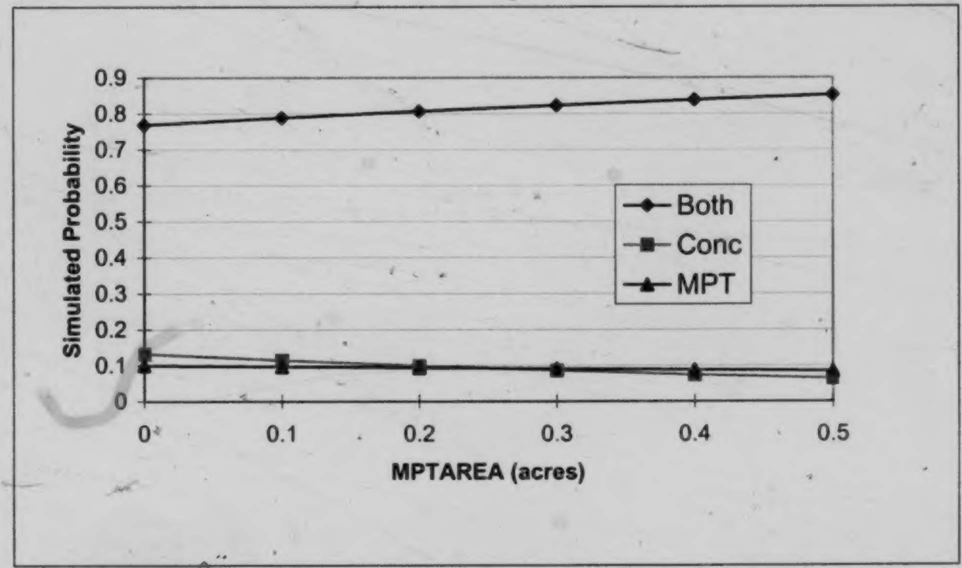

Fig 5.1c: Simulated Choice Probabilities for Change in Area Planted to MPT Fodder (Wet Season)

However, it is it is apparent that the probability of using both MPT fodder and purchased concentrates remains very high in the wet season. The greater outputs of MPT fodder reflected in a greater area planted result in continued complementary use of MPT fodder with purchased concentrates. This observation is also supported by the insignificant marginal effect on the variable MPTAREA observed in Table 5.4b for the MNL estimates for choice of MPT fodder alone in the wet season. Thus it appears that for the wet season, increased area planted to MPT fodder does not result in substitution for purchased concentrates. This observation may suggest other constraints to greater dependence on MPT fodder in the wet season. Such constraints could be associated with the availability of farm labor to allocate to MPT fodder pastures beyond some level. Available labor may be allocated to food and cash crops preferentially over being used for MPT fodder production for cattle feed.

5.5.2 Results of Simulated Choice Probabilities for the Dry Season

From Figure 5.2a, simulation results for the number of cows actually producing milk (INMILK) show that the probability of using both MPT fodder and purchased concentrate falls from more than 80 percent with zero milking cows to about 20 percent when the number of milking cows reaches three.

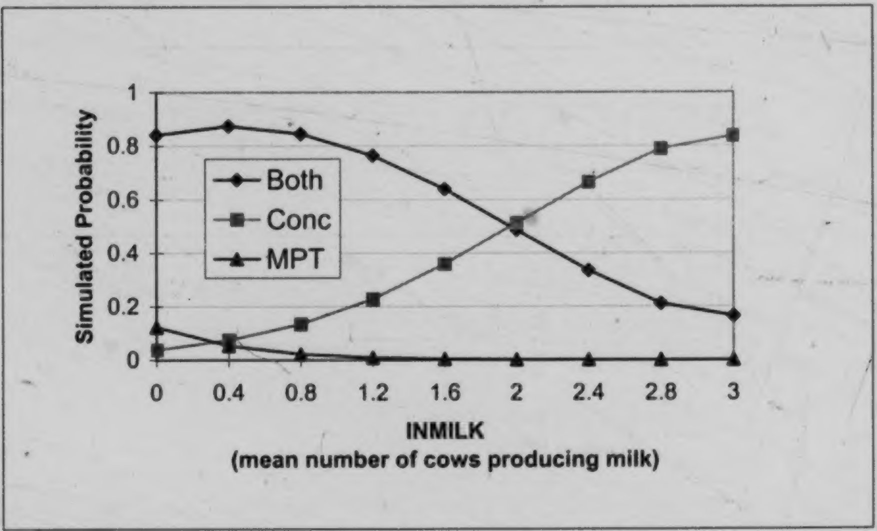

Fig 5.2a: Simulated Choice Probabilities for Change in Mean Number of Cows Producing Milk (Dry Season)

The probability of using purchased concentrates alone increases steadily from less than 10 percent when there are no cows producing milk, to above 80 percent with three cows producing milk. The probability of using both MPT fodder and purchased concentrates and the probability of using purchased concentrates alone coincide at the point where two cows are producing milk. The probability of using 'Both' or 'Conc' is about 48 percent at this point. The probability of using MPT fodder alone is highest, 12 percent when there are no cows producing milk. MPT fodder approaches zero probability of use when the number of milking cows is above one. These results suggest that the probability of using purchased concentrates is most likely when there are milk-producing cows and that this increases in direct proportion to the number of producing cows. MPT fodder appears to be viable for use where there is only one cow producing milk, after which the probability of MPT use approaches zero. This result is similar to the observations made in Section 5.3.4 from the MNL model D4 estimation results, where it was concluded that the more specialized dairy enterprise will expend more on yield-enhancing technologies (such as purchased concentrates) when milk productivity is higher (Zepeda, 1994; El-Osta and Morehart, 2000). The fact that probability of using MPT fodder approaches zero at figures above one milking cosuggests that there is a factor limiting MPT fodder use. This could possibly be the area of MPT fodder trees that must be planted to obtain feasible outputs of fodder harvested or else agronomic, resource and management constraints that contribute to low yields.

Reference to Figure 5.2b suggests a drop-off at the year 1995, as the year of first planting MPT fodder, when the probability of using both MPT fodder and purchased concentrates and MPT fodder alone begin to fall. First planting in 1995 indicates about four years experience with MPT fodder trees and the simulation results show that farmers with less than four years experience with MPT fodder planting have a lower probability of choosing feed technology bundles that incorporate At the planting date of 1995, the probability of using purchased concentrates alone overtakes the probability of using MPT fodder alone. The probability of purchased concentrates alone peaks at about 80 percent for first planting in 1999, the time when the survey was conducted. The sample mean of 1996.88 as the year of first planting MPT fodder indicates less than 2.5 years of experience with MPT fodder planting on average. The simulated probabilities for first planting in 1985, indicating about 14 years of experience with MPT fodder planting, show that the probability of using MPT fodder alone reaches a peak of about 75 percent. The probability of using both MPT fodder and purchased concentrates overtakes the use of MPT fodder alone after 1997, indicating less than 12 years of experience with MPT fodder planting.

These results suggest that it would take about 12 years of experience to induce probabilities of using MPT fodder alone to be above 50 percent for this group of farmers.

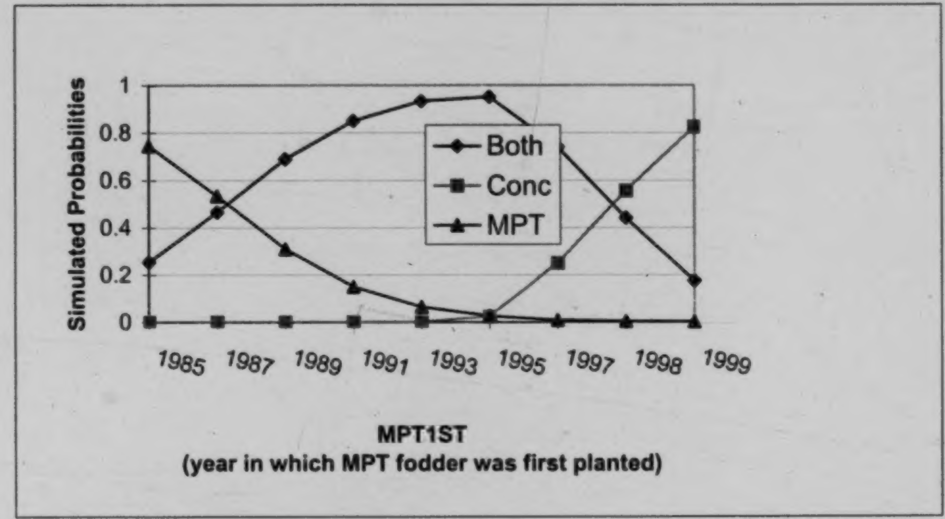

Fig 5.2b: Simulated Choice Probabilities for Change in Year in which MPT Fodder was First Planted (Dry Season)

This experience may be critical in overcoming agronomic, resource and management constraints to multi-purpose fodder tree productivity and in overcoming constraints to conservation and storage for dry season use. Information, demonstration of practices and results and extension support may be important in reducing the time required for this process of learning curve and to acquire experience.

From Figure 5.2c it is apparent that an increase in the area planted to MPT fodder will increase the probability of using both MPT fodder and purchased concentrates, whilst reducing the probability of using purchased concentrates alone. Greater outputs of MPT fodder are reflected in greater areas planted and this could result in extended complementary use of MPT fodder with purchased concentrates. The results continue to indicate however, that a greater area of MPT fodder will not increase the probability of using MPT fodder alone. This result is supported by the insignificant marginal effect on the variable MPTAREA observed in Table 5.5b for the MNL estimates for choice of MPT fodder alone in the dry season. The probability of using purchased concentrates alone approaches 50 percent as MPTAREA approaches zero, and this probability approaches zero percent at MPTAREA above 0.8 acres, whilst the use of both MPT fodder and purchased concentrates increases.

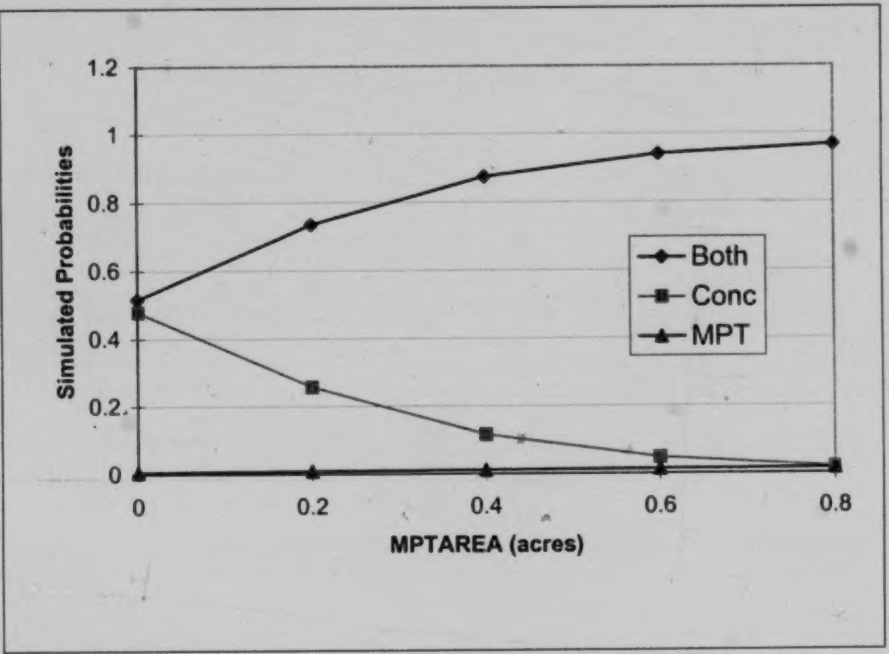

Fig 5.2c: Simulated Choice Probabilities for Change in Area Planted to MPT Fodder (Dry Season)

Evidently the complementary use of MPT fodder and purchased concentrates would prevail with larger areas planted to MPT fodder trees whilst complete substitution of MPT fodder for purchased concentrates does not seem likely to occur. This suggests a limiting constraint to the level of use of MPT fodder in the dry season, despite larger areas planted. Indeed, fodder outputs could still be limiting due to agronomic and resource constraints and management factors. For example as cited by Dzowela (1997), deferral of the fodder cutting date in the wet season from January to April significantly increases yields and re-growth of leaves for the dry season. In addition, crude protein content of leaves is reduced when leaves are dried in preparation for storage for the dry season. The variability in quantity and quality of feed from the field conditions use of MPT fodder and could contribute to continued use of purchased concentrates in order to ensure animal productivity through meeting dietary requirements such as for crude protein.

Chapter 6 - - Summary and Conclusions

This concluding chapter summarizes the study findings and highlights policy implications. The limitations of the study are noted, as are suggestions for further study.

6.1 Summary of the Background, Problem and Findings

A major challenge in smallholder farming systems is the poor quality and insufficient quantity of livestock feed, especially during the seven to nine months of the annual dry season. The major source of livestock nutrition for smallholder farmers in Zimbabwe is the graze and browse from communal grazing and woodlands areas. However, drastic changes occur in the nutritional quality of fodder between the wet and dry season in Zimbabwe and the quantitative availability of feed has been reduced by clearing of trees and land for raw materials and agriculture. Crop residues are the major dry season livestock feed, but these are generally inadequate quantitatively and have a low nutritional value in terms of crude protein content. The alternative sources of cattle feeds, with the adequate levels of crude protein content that are critical to animal productivity, are purchased commercial supplements and fodder production. Purchased concentrates are unaffordable by the majority of smallholder farmers who face credit and liquidity constraints. Commercially produced concentrates are, however, purchased for dairy cattle feed supplementation where milk is marketed. Fodder production, although potentially alleviating feed availability problems and reducing cash expenditures on supplementary feeds, has generally been constrained by the availability of arable land and labor due to the competing need for food and cash crop production during the main cropping season. It is not surprising therefore, that livestock feed availability and the accessibility of its use is central to the viability of smallholder farmer dairy production in Zimbabwe.

Agroforesty for fodder production, in the form of on-farm multi- purpose tree (MPT) fodder banks, has been introduced as a viable livestock feed alternative. The species of MPT fodder introduced to farmers in Chikwaka communal area have been shown to possess higher crude protein contents when fresh than commercially produced feeds. Thus, MPT fodder may potentially be a cash-saving source of high protein cattle feed for smallholder dairy farmers in Chikwaka Communal Area. This thesis research study has tried to achieve some understanding of the factors that may underlie adoption of this agroforestry technology, relative to purchased commercial feeds, by farmers in the chosen study area. This objective is achieved by examining the *ex post* feed technology choices and investments made by smallholder dairy farmers, in the context of multiple feed technology alternatives that are available to alleviate the challenges they face in provision of adequate animal feed throughout the year.

The major dietary requirements dictate that a cow consumes at least three percent of its body weight in dry matter (DM) and crude protein (CP) at the level of at least 14 percent of dry matter intake among other nutrients to ensure productivity. Chikwaka commual area dairy farmers may exploit any and all available feed resources in their feeding strategy. These include the use of communal grazing and browse resource, the use of crop residues, maize, pasture legumes and grasses, purchased concentrates and MPT fodder trees which all provide dry matter (DM) and varying levels of crude protein (CP) and other nutrients. However, the major challenge faced by smallholder dairy farmers is in provision of adequate levels of crude protein in the feeds given to dairy cows. The findings of this study indicate that the major trade-off in terms of components of the feed technology bundle are with the use of purchased concentrates and MPT fodder, the two feed sources that offer adequate levels of dietary crude protein. For purchased concentrates, this is because purchased concentrates will only be used if there are cows that are currently producing milk, since the revenue from milk sales evidently justifies costs incurred for feed purchase. For the case of MPT fodder trees, the years of experience with planting the trees, seasonal fluctuation in plant material availability and the area invested in planting the trees appear to be important determinants of use.

In general, the un-specialized dairy farmers for whom crops are the primary source of income are less likely to use MPT fodder or purchased concentrates to feed their dairy cows. This reflects the possible lack of investment of land and labor resources in MPT fodder production and lack of revenue from milk sales. The use of purchased concentrates appears to be closely linked to the scale of the dairy enterprise and the level of productivity (that is, technical efficiency as measured by ratio of the dairy herd that is actually producing milk) hence the expectation of financial return. In the wet season, at levels of operation where more than 50 percent of the dairy herd is producing milk, the probability of using purchased concentrates rises sharply and peaks. This suggests that use of purchased concentrates alone is compatible with high levels of technical efficiency and specialization, whilst the use of both MPT fodder and purchased concentrates is compatible with lower levels of efficiency and specialization in dairy production. The use of MPT fodder alone does not occur for the larger scale and more specialised productive dairy enterprise. This tendency seems to explain the complementary relationship observed between purchased concentrates and MPT fodder in the wet season when MPT fodder outputs are highest.

Farmers would likely continue to use purchased concentrates as long as there are cows producing milk which provides an economic incentive to off-set the cost of purchased feeds. Similarly, for the dry season, an absolute number of three milking cows results in an 80 percent probability of using purchased concentrates. The probability of using both MPT fodder and purchased concentrates falls from above 80 percent for zero cows producing milk, to less than 20 percent when the number of milking cows reaches three. The probability of using MPT fodder alone is highest when there are no cows producing milk, and this approaches zero with one or more milking cows. This suggests that there is a limiting factor in the use of MPT fodder, possibly due to low fodder outputs such that MPT fodder harvested may not be adequate to meet the crude protein requirements of the milking herd.

In the dry season, the farmer's years of experience in growing and conserving MPT fodder trees and the area planted may determine fodder output and the ability to use MPT fodder. In general, however, agronomic and resource constraints and management factors may determine the farmer's ability to use MPT fodder. Availability may be influenced by fodder cutting practices in terms of timing to maximize yields and re-growth, whilst labor constraints in the wet season may preclude harvesting of MPT fodder for use. However, the higher is the total number of dairy cows owned (both producing and non-producing), the probability increases of using both MPT fodder and purchased concentrates in the dry season.

MPT fodder trees are used together with purchased concentrates by the majority of farmers and to a greater extent in the wet season than in the dry season. This may reflect the ability to carry-over surplus feed from the wet season. Indeed, the probability of using purchased concentrates alone in the dry season approaches zero for areas planted to MPT fodder trees of above 0.8 acres, whilst the probability of using purchased concentrates alone peaks when the area planted to MPT fodder tree falls to approach zero acres. Greater outputs of MPT fodder, reflected in greater areas planted, lead to greater complementary use of MPT fodder with purchased concentrates.

The results from this study indicate that the use of MPT tree fodder, though it may be a good source of crude protein is not currently a complete substitute for purchased concentrates. The results indicate joint use of purchased concentrates and MPT tree fodder, even during the wet season when one expects output of MPT fodder to be at its peak. Greater years of experience or familiarity with planting the MPT fodder trees and larger areas planted to MPT fodder trees increase the probability of MPT fodder substituting for the use of purchased concentrates, to a maximum of 20 percent, in the wet season. In contrast, the probability of using both MPT fodder and purchased concentrates rises above 80 percent with more years of experience and greater areas planted. The opportunity for MPT fodder alone substituting for the use of purchased concentrates is higher in the dry season, when the probability of using MPT fodder alone is more than 50 percent for farmers with 12 or more years of experience with MPT fodder. MPT fodder use in the dry season peaks at 75 percent with 14 years of experience. This suggests that other constraints to MPT fodder use, such as labor availability, may be observed in the wet season. It should be noted, however, that the calculated sample mean for the years of experience indicates a value of less than two and a half years for these farmers suggesting that there would still be a long time to wait for substitution, arising from years of experience, to occur. However, the level of experience or the learning curve with growing MPT fodder trees does appear to be a crucial determinant of the ability to use MPT fodder in the dry season. It may be concluded therefore that extension support may be a crucial determinant for the prospect of MPT fodder as a cash-saving alternative to purchased concentrates in the dry season.

The results for the wet season models also indicate that farming households with higher potential family labor availability in the wet season are likely to use either MPT fodder trees or purchased concentrates or both. When farmers do not experience problems of inadequate access to communal grazing, they are less likely to use purchased concentrates alone but are more likely to use both MPT fodder and purchased concentrates. Households that own an ox-drawn scotch-cart are less likely to use purchased concentrates, possibly being more equipped to collect and transport plant-based feeds such as crop residues, grass, pasture grasses and legumes and MPT fodder to store for use. .

6.2 Implications of the findings of the study

The results of this analysis enable us to highlight some considerations for agroforestry technology, practice, policy, research and extension that is related to the multi-purpose tree (MPT) fodder bank technology that is targeted for smallholder dairy farmers. Given the assumptions and limitations of this analysis, the following issues appear to be pertinent with regards to lessons and implications stemming from the findings of this study as discussed in the Sections above:

1. Farmer motivation, in terms of the importance of the dairy enterprise as an income source, is important in targeting farmers that may be willing to invest resources of labor, land and learning time to MPT fodder tree production. Higher profit expectations from crops reduces the probability of investment in MPT fodder production;

2. Marginal dairy farmers in this group, with only one cow producing milk, are more likely to use the MPT fodder technology. This may suggest a scale constraint for farmers with more than one milking cow. Consequently, there is a need to investigate the role of small areas planted to MPT fodder relative to other agronomic, resource and management constraints in determining potential yields;
3. The incentive of financial return from milk-producing cows favors the use of purchased concentrates. Although the cost of purchased feeds has risen in recent years and MPT fodder is reported to have higher levels of crude protein content, purchased concentrates are still purchased by efficient and specialized smallholder dairy farmers. This tendency may reflect a possible scale constraint on the use of MPT fodder for more than one producing cow such that quantities available are inadequate to meet animal dietary needs for crude protein.
4. Use of purchased concentrates may be due to the observation of more profitable returns from milk when using purchased feeds than is the case with MPT fodder technology. The research findings reported here suggest that experience over time will induce greater use of MPT fodder, suggesting a learning curve. However, long periods for increased use of MPT fodder, representing about 12 to 14 years of investment in time and effort to gain experience are required to induce a 50 to 75 percent probability of MPT use. These may be shortened through extension support, training and demonstration of tangible results given that on average, the farmers in this sample have less than two and a half years of experience with the fodder trees. It may be an issue, however, that 78 percent of farmers in the sample under study reside in Mwanza Ward where there has been limited access to extension support in MPT fodder production because of the distance and absence of a resident extension officer, as compared to Gutu Ward which is nearest to the milk collection center and has a resident ICRAF extension officer;
5. The objective of allewiating dry season livestock feed shortages through use of MPT fodder appears to be constrained by low outputs of MPT fodder. This reflects the small areas allocated and may be associated with lack of experience in growing MPT fodder trees. However, the extent to which MPT fodder assists in alleviating dry season feed bottlenecks may need to be measured quantitatively, which was beyond the scope of this study;
6. Limited experience with planting MPT fodder trees may also be reflected in a limited ability to carry-over and store MPT fodder from the wet season for use in the dry season. This observation highlights the opportunity for targeting increased use of MPT fodder in the wet season, when availability of MPT fodder is good, possibly to substitute for purchased concentrates, rather than targeting extensive dry season use since the latter clearly is not

being achieved. However, the role of wet season labor constraints in limiting possibilities for increased use of MPT fodder may need to be investigated first.

The above considerations, analyzed in the context of the assumptions and limitations of this study, may assist stakeholders in designing and targeting interventions that have a reasonable probability of adoption and integration in smallholder farming systems.

6.3 Limitations and recommendations for further study

A major limitation of this study was the absence of complete quantitative yield data for MPT fodder trees and milk production and lack of data on actual expenditures on the dairy feed activity and actual feed rations given to animals over the season. This would constitute alternative specific information on the feed sources. Similarly, there is a lack of time series data on dairy feed activity from the time when MPT fodder planting was initiated. These types of data would require a more intensive and time consuming collection process to track daily input and output activity and to elicit farmer recollection of activities over the past few years. This information would have been useful to enable a more complete economic assessment of the extent to which each of the feed resources is used and contributes to dairy cow productivity and revenue quantitatively throughout the year. These activities could also be tracked over time to highlight the effect of dynamics on the feed technology portfolio and choices of farmers. This could provide a more accurate indicator of the level of use of MPT fodder and purchased concentrates and may highlight the extent to which MPT fodder may indeed be a lower cost alternative and the extent to which substitution and/or complimentarity occurs. More broadly, the interaction of resource allocation decisions for other household consumption and production activities with the decisions for the dairy enterprise needs to be investigated to get a more complete picture of trade-offs and the decision making process. This relates particularly to the benefits and costs of MPT fodder banks given the opportunity costs of land and labor for food and cash crop production.

A major concern with MPT fodder production is the low yields observed on-farm by farmers relative to results of experimental station and on-farm farmer trials led by scientists. Therefore, the agronomic, resource and management issues that determine the productivity of on-farm MPT fodder production may need to be investigated and addressed.

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APPENDIX I: Survey Questionnaire

Smallholder farmer resource allocation for cattle feeding in Chikwaka Communal Area

PART A:

Introduction

Greetings. Your household is being visited today as part of a study to learn about the different resources and practices you use for feeding your cattle. By participating in this survey you will be assisting a Zimbabwean student, Sibongile Moyo who is studying at the University of Alberta in Canada. This study is part of the requirements for a Master's degree in agricultural economics. The information to be collected from this study will also help in understanding which resources and practices are most important to you in feeding your cattle and why. Participation is voluntary and your responses will be kept confidential. The appropriate district and village leaders have given permission for this study to be carried out.

HH Code No.___________ HH Name____________________ Ward_______________________

Village_______________________ Date _______________ Enumerator___________________

Start Time___________ Finish Time__________________

Survey Status _________ Complete 1 Incomplete 2

Supervisor's Observations
How many errors were found in checking the questionnaire? ______
Is the survey satisfactory? Yes....1 No.....2

The wages of the enumerator will be reduced by $20 for each survey which is unsatisfactory.

Section I: Household characteristics

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1. Sex of respondent. *Do not ask.*
Male........1 Female.....2

2. What is the sex of the household head?
Male........1 Female.....2

3. **a)** Which family member is responsible for the dairy enterprise?
Wife/Female Head...1 Male Head....2 other....3
Specify other _______________________________________

b) Who is responsible for cattle feeding?
Wife/Female Head.1 Male Head...2 worker...3 other....4
Specify other ___________________

Ask to speak to the family member identified in 3a), if not there come back another time or speak to the person responsible for cattle feeding identified in 3b) if available.

The following questions 4 to 7 should be addressed to the person identified in question 3 as responsible for the dairy enterprise or cattle feeding.

4. In which of the following age groups is the household member?
Below 30....[1] 31 - 40....[2] 41 – 60....[3] 61 +....[4]

5. What is the household member's highest educational qualification?
None..[1] primary..[2] secondary..[3] diploma..[4] adult lit..[5]

6. Has the household member had any agricultural training?
master farmer ...[1] diploma....[2] other....[3] none....[4]
specify other____

7. What is the household member's full time occupation?
Family farm work....[1] Rural off-farm agriculture work...[2] Rural Non-Agriculture work [3] Work in town...[4]
Other (specify) ________________________________.[5]

8. What is the household head's full time occupation?
Family farm work....[1] Rural off-farm agriculture work...[2] Rural Non-Agriculture work [3] Work in town...[4]
Other (specify) ______________________________.[5]

9. **a)** How many people live in this household? __________
b) How many adult females are there in this household? ______
c) How many adult males are there in this household? _______

Section II: Indicators of motivation

A. Memberships and participation

1. In which year did you join the Dairy association? _________

2. Are you registered as a member of the Chikwaka dairy co-operative as of 1999? [✓ Yes....[1]] No.....[2]

3. Did you attend the June 1999 LFA meeting held at the milk collection centre, chaired by Mr. Hakutangwi of ARDA? Yes....[1] No.....[2]

B. Adoption of MPTs (miti yemafuro)

1. In which year did you first learn about MPT fodder trees?
1994..[1] 1995..[2] 1996..[3] 1997..[4] 1998..[5] 1999..[6]
If response is now go to question 4b) otherwise go to 2.

2. **a)** From whom did you learn about MPT fodder trees? *Circle the appropriate number and elaborate other source.*

ICRAF	Agritex	Field Day	Neighbor	Other (specify)
1	2	3	4	

If response is field day (3) go to question 2b),otherwise skip.
b) What was the topic for the field day and where was it held? ____________________________

3. a) Have you ever planted MPT fodder trees?

Yes...1 No....2

If no go to question 4, if yes continue.

b) In which year did you first plant the fodder trees? ________

c) Do you still have MPT fodder trees growing?

Yes....1 No.....2

d) Did you harvest and feed any MPT fodder in ______? *Ask for each season and insert code in table, 1-Yes and 2-No.*

Late dry season Aug-Dec 1998	**Wet season** Jan-May 1999	**Early dry season** June-July 1999

Skip question 4

4. a) Why did you never plant the fodder trees? *Circle appropriate reason/s and elaborate other.*

No land	**No interest**	**No skill**	**No seed**	**No fence**	**Other 2 (specify)**
1	2	3	4	5	

b) Would you consider planting the fodder trees? C*ircle appropriate response and briefly write reason.*

Yes....1 Why?___________________________________

No.....2 Why?___________________________________

***Don't know.....*3**

C. Cash orientation

1. a) Have you ever received credit to acquire cattle (cash or animal)? *Heifer project cows included.*

Cash....1 Animal....2 Cash and animal....3 Never....4

If never, go to question 2.

b) How many _________ did you acquire on this credit scheme? *Ask for each class of cattle and insert number of animals under the relevant class/es.*

Class	**Bull**	**Exotic**	**Draught**	**Indigen**	**Other**
No.					

2. a) Did you receive income (either cash and/or in kind) from ____________? *Point to the cards and ask for each income source and tick all sources mentioned in the table below.*

b) Amongst the sources of income that you indicated, how would you **rank** them from most **important** to least important? *Lay out the cards with all the income sources ticked in question 2a) and have them order the cards from most to least important.*

c) How much cash income in $ did you receive from ________ over the last year? *Ask for each income source ticked in 2a).*

Source of Income	a) Tick	b) Import rank	c) amount$	d) rank$$
1. Remittance				
2. milk				
3. crop				
4. gardens				
5. cattle				
6. crafts				
7. beer brew				
8. brick make				
9. pension				
10. Livestock				
11.Job (spec)				
12. Other				

d) So did you receive the most cash $ from ____________?
So did you receive the 2nd most cash $ from __________?
So did you receive the 3rd most cash $ from ___________?
....*and so on*

Ask for each income source in the order of the cash amount stated in 2c) from most to least.

3. **a)** Do you keep records? Yes.... 1 No.... 2

If yes go to 3b) otherwise go to Section III.

b) In which year did you start keeping the records? __________

c) What do the records cover? *Summarise in one line.*

Section III: Assets and resource allocation

D. A Physical Assets

1. ***Observation by the enumerator.***

a) How many houses are there on the compound? __________

b) The best house in the compound is best described as:

Pole & dagga.. 1 ***Brick & thatch..*** 2 ***Brick & asbestos/iron...*** 3

2. Do you have a well (mugodi) at this homestead?
Yes..... 1 No...... 2

3. Does this household own a bicycle? Yes.... 1 No..... 2

4. Does this household own a scotch-cart? Yes.... 1 No..... 2

A1. Land

1. How many acres of land do you have as __________? *Ask for each land category then add up to get the total land area.*

Category	Area
Crop fields	
Gardens	
Homestead	
Pastures	
Private paddocks	
Total land area	

2. How many acres of land do you use for _________ *Ask for each land use/allocation category.*

Land use/allocation	**Area**
Maize for human consumption	
Maize for cattle feed	
Pasture grasses and legumes	
MPT fodder trees pasture	
Private paddocks	

3. **a)** Do you have any land area available as fenced communal paddocks? Yes....1 No.....2 *Iif no skip 3b).*

b) What is the area of the communal paddock available to you?_____________

B. Labor

1. **a)** Did you hire any full time workers in __________ ? *Ask for each season. Code: 1-Yes, 2-No. If no skip 1b)*

b) How many full time workers (working everyday for at least one month) did you hire in ? *Ask for each season. Insert number in table.*

	Late dry season Aug-Dec 1998	**Wet season** Jan-May 1999	**Early dry season** June-July 1999
a Yes/No			
b Number			

2. **a)** Did you hire any part time workers in __________ ? *Ask for each season. Ask both question and a) and b) for one season at a time Code: 1-Yes, 2-No. If no skip 2b), 3 to 5.*

b) Lets define a labour day as one person working for one day of up to 10 hours or who is paid the equivalent of a day's work (mgwazo). How many part time labour days did you **hire** (marikicho) in ____________ ? *Ask for each season.*

	Late dry season Aug-Dec 1998	**Wet season** Jan-May 1999	**Early dry season** June-July 1999
a Yes/No			
b Number			

If zero days of labour hired, skip questions 3 to 5.

3. **a)** How much did it cost you to hire one full time worker for a month in ______________*(insert season)? Ask both 3 a) and b) for one season at a time. Indicate payment in kind and try to get the estimated cash $ equivalent.*

b) How much did it cost you to hire one worker part time worker for a day's work in *(insert season)*?

	Late dry season Aug-Dec 1998	**Wet season** Jan-May 1999	**Early dry season** June-July 1999
a full time			
b part time			

4. **a)** Did you use any hired labour (both full time and part time) for ___________ *(insert activity)* in the late dry season? *Point to the cards with each activity and tick all activities mentioned.*

Ask questions 4 a), b) and c) for one activity at a time.

LATE DRY SEASON Aug-Dec 1998									
	a) Tick			**b) No. Days**			**c) Rank**		
Activity	**F**	**P**	**To**	**F**	**P**	**To**	**F**	**P**	**Tot**
Food crops									
Herding cattle									
Dairy & fodder									
Other(specify)									

b) Lets define a labour day as one person working for one day of up to 10 hours or who is paid the equivalent of a day's work (*mgwazo*). How much hired labour (in labour days) did you use for __________ in the late dry season? *Ask for each activity ticked. Add up hours to make a labour day.*

c) So did you use the most hired labour on ___________?
So did you use the 2nd most hired labour on __________?
....*and so on*

Ask for each activity ticked in the order of the number of labor days allocated in 4b), most to least.

5. a) Did you use any hired labour (both full time and part time) for ___ _____ in the wet season? *Point to the cards with each activity and tick all activities mentioned. Ask a), b) and c) for one activity at a time.*

WET SEASON Jan-May 1999									
	a) Tick			b) No. Days			c) Rank		
Activity	F	P	To	F	P	To	F	P	To
Food crops									
Herding cattle									
Dairy & fodder									
Other(specify)									

b) Lets define a labour day as one person working for one day of up to 10 hours or who is paid the equivalent of a day's work (mgwazo). How much hired labour (in labour days) did you use for __________ in the wet season? *Ask for each activity ticked. Add up hours to make a labour day.*

c) So did you use the most hired labour on ___________?
So did you use the 2nd most hired labour on __________?
....*and so on*

Ask for each activity ticked in the order of the number of labor days allocated in 5b), most to least.

6. a) Did you use any hired labour (both full time and part time) for __________ in the early dry season? *Point to the cards with each activity and tick all activities mentioned. Ask a), b) and c) for one activity at a time.*

EARLY DRY SEASON Jun-Jul 1999									
	a) Tick			b) No. Days			c) Rank		
Activity	F	P	To	F	P	To	F	P	To
Food crops									
Herding cattle									
Dairy & fodder									
Other(specify)									

b) Lets define a labour day as one person working for one day of up to 10 hours or who is paid the equivalent of a day's work (mgwazo). How much hired labour (in labour days) did you use for __________ in the early dry season? *Ask for each activity ticked. Add up hours to make a labour day.*

c) So did you use the most hired labour on ___________?
So did you use the 2nd most hired labour on __________?
....*and so on*

Ask for each activity ticked in the order of the number of labor days allocated in 6b), most to least.

C. Herd size and composition

1. a) Do you keep cattle for _________? *Point to the card with each reason and tick all reasons mentioned. Elaborate other.*

Reason	Tick	Rank	No	More?	e)
Draught					
Milk					
Meat/sale					
Social/Asset					
Other					

Constraints
1. Cash
2. Grazing
3. Feeds
4. Labour
5. Other(spec)

b) How would you **rank** these reasons for keeping cattle in terms of contribution to overall household wellbeing (food, cash, inputs). *Point to the cards with each reason ticked in a) and have the respondent order them.*

c) How many cattle do you keep for ____________? *Ask for each reason ticked in a).*

d) Would you like to have more cattle for ____________? *Ask for each reason/role ticked in a) and code: 1-Yes and 2- No.*

d) What is the primary reason for you not having those cattle numbers for ___________? *Ask for each reason/role where response to d) is no. Insert code for constraint.*

2. **a)** In the late dry season, how many __________ (*insert cattle class)* did you have? *Ask for each class of cattle. Then add classes to get the total herd for the season.*

Class	Late dry Aug-Dec'98	Wet Jan-May'99	Early dry Jun-Jul'99
Dairy Cows			
Cows in milk			
Dry & heifers			
Total			
Breeds			
Indigenous			
Exotic/Cross			
Total			

If the farmer records a zero for total dairy herd in all three seasons go to question 3, otherwise go to D.

b) In the wet season, how many _________ (*insert cattle)* did you have? *Ask for each class of cattle. Then add classes to get the total herd for the season.*

c) In the early dry season, how many _________ (*insert cattle class)* did you have? *Ask for each class of cattle. Then add classes to get the total herd for the season*

3. In which year did you last have a dairy cow(s)? ____________

D. Feed Resources

1. **a)** In the late dry season, did you use ____________ (*insert feed source)* to feed your cattle?. *Ask for each feed source and insert a tick for each feed used.*

Feeds source	Late dry Aug-Dec98	Wet Jan-May99	Early dry Jun-Jul'99
1. Communal grazing			
2. Crop residues or stover			
3. Purchased Concentrates			
4. Pasture grasses & legumes			
5. MPT fodder tree pastures			
6. Maize			

b) In the wet season, did you use ____________ (*insert feed source)* to feed your cattle? *Ask for each feed option and insert a tick for each option used.*

c) In the early dry season, did you use ____________ *(insert feed option)* to feed your cattle?. *Ask for each feed option and insert a tick for each option used.*

2. What other sources of feed (options) did you use to feed your cattle in ______________? *Ask for each season.*

Feed source	**Late dry** Aug-Dec'98	**Wet** Jan-May'99	**Early dry** Jun-Jul'99
Other 1			
Other 2			

3. **a)** Do you have a problem finding adequate feed for your cows? Yes...1 No...2

If yes go to 3b) otherwise proceed to E.

b) What would you say is the reason for the feed problem? *Summarise in one line.*

____

E. Fuel/Energy Sources

1. **a)** In the late dry season, did you use ____________ *(insert fuel type)?. Ask for each fuel type and insert a tick for each fuel used.*

Fuel Type	**Late dry** Aug-Dec'98	**Wet** Jan-May'99	**Early dry** Jun-Jul'99
1. Wood			
2. Maize cobs			
3. Dung			
4. Paraffin			
5. Gas			
6. Electricity			
7. Petrol/diesel			
8. Solar			
9. Other			

b) In the wet season, did you use ____________ *(insert fuel type)?*

c) In the early dry season, did you use ____________ *(insert fuel type)?*

2. **a)** Do have a problem finding adequate fuelwood?

Yes...1 No...2

If yes go to 2b) otherwise skip.

b) What would you say is the reason for your fuelwood problem? *Summarise in one line.*

____

PART B: Alternative Specific Attributes

Section I Labour use

Labour use includes all activities such as planting, weeding, watering, harvesting, feeding, mixing, herding and others involved in using or preparing the feed option for use by cattle.

1. **a)** Based on all the feed options that you could use for your cattle, how would you **rate** the **hired labour time** (both full time and part time – marikicho) you would need to spend on _____________ *(insert feed type)* **per cow** in the late dry season? *Rating: 1-high/plenty/most, 2-medium/average, 3-low/little/least, 4-don't know. Ask for each feed option.*

	Rating		
Feeds source/option	**Late dry**	**Wet**	**Early dry**
1. Communal grazing			
2. Crop residues or stover			
3. Purchased Concentrates			
4. Pasture grass & legume			
5. MPT fodder pastures			
6. Maize			

b) Based on all the feed options that you could use how would you **rate** the **hired labour time** (both full time and part time – marikicho) you would need to spend on _____________ *(insert feed type)* **per cow** in the wet season? *Rating: 1-high/plenty/most, 2-medium/average, 3-low/little/ least, 4-don't know. Ask for each feed option.*

c) Based on all the feed options that you could use how would you **rate** the **hired labour time** (both full time and part time – marikicho) you would need to spend on _____________ *(insert feed type)* **per cow** in the early dry season? *Rating: 1-high/plenty/most, 2-medium/average, 3-low/little/ least, 4-don't know. Ask for each feed option.*

2. **a)** Based on all the feed options that you could use for your cattle, how would you **rate** the **total labour time** (both family and hired) you would need to spend on _____________ *(insert feed type)* **per cow** in the late dry season? *Rating: 1-high/plenty/most, 2-medium/average, 3-low/little/least, 4-don't know. Ask for each feed option.*

	Rating		
Feeds source/option	**Late dry**	**Wet**	**Early dry**
1. Communal grazing			
2. Crop residues or stover			
3. Purchased Concentrates			
4. Pasture grass & legume			
5. MPT fodder pastures			
6. Maize			

b) Based on all the feed options that you could use how would you **rate** the **total labour time** (both family and hired) you would need to spend on _____________ *(insert feed type)* **per cow** in the wet season? *Rating: 1-high/plenty/most, 2-medium/average, 3-low/little/ least, 4-don't know. Ask for each feed option.*

c) Based on all the feed options that you could use how would you **rate** the **total labour time** (both family and hired) you would need to spend on _____________ *(insert feed type)* **per cow** in the early dry season? *Rating: 1-high/plenty/most, 2-medium/average, 3-low/little/ least, 4-don't know. Ask for each feed option.*

3. **a)** Based on all the feed options that you could use for your cattle, how would you **rate the availability in terms of quantity** of ____________ *(insert feed type)* in the late dry season? *Rating: 1-high/plenty/most, 2-medium/average, 3-low/little/least, 4-don't know. Ask for each feed option.*

	Rating		
Feeds source/option	**Late dry**	**Wet**	**Early dry**
1. Communal grazing			
2. Crop residues or stover			
3. Purchased Concentrates			
4. Pasture grass & legume			
5. MPT fodder pastures			
6. Maize			

b) Based on all the feed options that you could use how would you **rate the availability in terms of quantity** of ____________ *(insert feed type)* in the wet season? *Rating: 1-high/plenty/most, 2-medium/ average, 3-low/little/ least, 4-don't know. Ask for each feed option.*

c) Based on all the feed options that you could use how would you **rate the availability in terms of quantity** of ____________ *(insert feed type)* in the early dry season? *Rating: 1-high/plenty/most, 2-medium/ average, 3-low/little/ least, 4-don't know. Ask for each feed option.*

4. **a)** Based on all the feed options that you could use for your cattle, how would you **rate the availability in terms of quality** of ____________ *(insert feed type)* in the late dry season? *Rating: 1-high/plenty/most, 2-medium/average, 3-low/little/least, 4-don't know. Ask for each feed option.*

	Rating		
Feeds source/option	**Late dry**	**Wet**	**Early dry**
1. Communal grazing			
2. Crop residues or stover			
3. Purchased Concentrates			
4. Pasture grass & legume			
5. MPT fodder pastures			
6. Maize			

d) Based on all the feed options that you could use how would you **rate the availability in terms of quality** of ____________ *(insert feed type)* in the wet season? *Rating: 1-high/plenty/most, 2-medium/ average, 3-low/little/ least, 4-don't know. Ask for each feed option.*

e) Based on all the feed options that you could use how would you **rate the availability in terms of quality** of ____________ *(insert feed type)* in the early dry season? *Rating: 1-high/plenty/most, 2-medium/ average, 3-low/little/ least, 4-don't know. Ask for each feed option.*

5. Where did you find graze and browse in ____________ *(insert season)? Ask for each season and insert codes from the list of locations below.*

Communal grazing	**Late dry** Aug-Dec'98	**Wet** Jan-May'99	**Early dry** Jun-Jul'99

Locations

1.communal paddock	4.neighbouring villages
2.designated grazing area	5.private contour bunds
3.commercial farms	6.other (specify)

Section III Land and cash use

6. **a)** Based on all the feed options that you could use for your cattle, how would you rate the **land needed** to use ____________ *(insert feed)* **per cow** in the late dry season? *Rating: 1-high/plenty, 2-medium/average, 3-low/little, 4-don't know. Ask for each feed option.*

	Rating		
Feeds source/option	**Late dry**	**Wet**	**Early dry**
1. Communal grazing			
2. Crop residues or stover			
3. Purchased Concentrates			
4. Pasture grass & legume			
5. MPT fodder pastures			
6. Maize			

b) Based on all the feed options that you could use how would you **rate** the **land needed** to use ____________ *(insert feed type)* **per cow** in the wet season? *Rating: 1-high, 2-medium/average, 3-low/little, 4-don't know. Ask for each feed option.*

c) Based on all the feed options that you could use would you **rate** the **land needed** to use ____________ *(insert feed type)* **per cow** in the early dry season? *Rating: 1-high/plenty, 2-medium/average, 3-low/little, 4-don't know. Ask for each feed option.*

7. **a)** Based on all the feed options that you could use for your cattle, how would you **rate** the **cash needed** (for input purchase – fence, hired labour, seed, seedlings, fertiliser, shed/pit, chemicals, etc) to use ____________ *(insert feed type)* **per cow** in the late dry season? *Rating: 1-high, 2-medium/average, 3-low/little, 4-don't know. Ask for each feed option.*

	Rating		
Feeds source/option	**Late dry**	**Wet**	**Early dry**
1. Communal grazing			
2. Crop residues or stover			
3. Purchased Concentrates			
4. Pasture grass & legume			
5. MPT fodder pastures			
6. Maize			

d) Based on all the feed options that you could use how would you **rate** the **cash needed** (for input purchase – fence, hired labour, seed, seedlings, fertiliser, chemicals, etc) **per cow** to use____________ *(insert feed type)* in the wet season? *Rating: 1-high, 2-medium/ average, 3-low/little, 4-don't know. Ask for each feed option.*

e) Based on all the feed options that you could use how would you **rate** the **cash needed** (for input purchase – fence, hired labour, seed, seedlings, fertiliser, chemicals, etc) **per cow** to use ____________ *(insert feed type)* in the early dry season? *Rating: 1-high/plenty, 2-medium/average, 3-low/little, 4-don't know. Ask for each feed option.*

8. **a)** Did you buy any concentrates (e.g. dairy meal) in __________ *(insert season) Tick. Ask both a) and b) for one season at a time.*

b) How many 50kg bags of concentrates did you buy in __________ *(insert season)? Ask for each season .*

Purchased Concentrates	**Late dry** Aug-Dec'98	**Wet** Jan-May'99	**Early dry** Jun-Jul'99
a) Tick if purchased			
b) No. of bags			

Section IV Perceived benefits and constraints

9. **a)** What do you see as the one biggest benefit/advantage of using __________ *(insert feed option)* in the late dry season? *Ask for each feed option. Insert code from list of benefits below. Elaborate others.*

Feeds source/option	**Late dry**	**Wet**	**Early dry**
1. Communal grazing			
2. Crop residues or stover			
3. Purchased Concentrates			
4. Pasture grasses & legumes			
5. MPT fodder tree pastures			
6. Maize			

Benefits

1. Short distance, low transport cost
2. Little demand on land
3. Low skill/info need
4. Cheap, abundant
5. Good animal health
6. Good profits
7. Good milk yield
8. Good milk quality
9. Other (specify)

b) What do you see as the one biggest benefit/advantage of using __________ *(insert feed option)* in the wet season? *Ask for each feed option. Insert code from list of benefits below. Elaborate others.*

c) What do you see as the one biggest benefit/advantage of using __________ *(insert feed option)* in the early dry season? *Ask for each feed option. Insert code from list of benefits below. Elaborate others.*

10. **a)** What is the biggest constraint to using __________ *(insert feed option)* in the late dry season? *Ask for each feed option. Insert code for the* **one** *biggest constraint mentioned from the list below.*

b) What is the biggest constraint to using __________ *(insert feed option)* in the wet season? *Ask for each feed option. Insert code for the* **one** *biggest constraint mentioned from the list.*

Feeds source/option	**Late dry**	**Wet**	**Early dry**
1. Communal grazing			
2. Crop residues or stover			
3. Purchased Concentrates			
4. Pasture grasses & legumes			
5. MPT fodder tree pastures			
6. Maize			

Constraints

1.Land
2.Seed/lings
3.Labour
4.Cash
5.Fertiliser
6.Shed/pit
7.Fencing
8.Transport
9.Implements
10.Chemicals
11.Skills/info
12.Other (specify)

c) What is the biggest constraint to using __________ *(insert feed option)* in the early dry season? *Ask for each feed option. Insert code for the* **one** *biggest constraint mentioned from the list above.*

Certification: I certify on my honour that this interview, according to the agreement I have made as an enumerator has been conducted honestly and completely.

PRINT NAME __________ SIGNATURE __________ DATE COMPLETED __________

5

APPENDIX II:

Results of MNL Model W1 tested on wet season data

```
              +----------------------------------------------+
              | Multinomial Logit Model                      |
              | Maximum Likelihood Estimates                 |
              | Dependent variable                    CC     |
              | Weighting variable                   ONE     |
              | Number of observations               118     |
              | Iterations completed                   8     |
              | Log likelihood function        -68.18588     |
              | Restricted log likelihood      -135.9407     |
              | Chi-squared                     135.5096     |
              | Degrees of freedom                    48     |
              | Significance level              .0000000     |
              +----------------------------------------------+
+--------+---------------+----------------+--------+---------+------
Variable | Coefficient|Standard Error |b/St.Er.|P[|Z|>z]| Mean of X|
+--------+---------------+----------------+--------+---------+------
          Characteristics in numerator of Prob[Y = 1]
 Constant 4.642147933     3.1043872      1.495  .1348
 MPT1ST  -1.374803383     .59973500     -2.292  .0219 3.8805085
 JOINDAR  .8913503211E-01 .13317502       .669  .5033 9.7381356
 INMDAR  -1.085712100     3.2237441      -.337  .7363 .39016949
 CROP1ST -3.908615249     1.3227920     -2.955  .0031 .16101695
 HERDF    1.977834808     1.4338047      1.379  .1678 .60847458
 MAIZTOT  1.686550000     3.0496364       .553  .5802 .40974576
 LANDPRB  2.514732423     1.2390982      2.029  .0424 .34745763
 DARYHER  .8687823401     .66673779      1.303  .1926 2.6271186
 INMILK   1.464404766     1.9322333       .758  .4485 1.1186441
 DELIVY  -.8169465794     1.3356068      -.612  .5408 .35593220
 MAIZLAB -1.056975759     .58107147     -1.819  .0689 2.3282203
 MPTAREA  10.20597675     3.7613158      2.713  .0067 .24800847
 RECORDY  .1487578279     1.2538035       .119  .9056 .37288136
 LFAYES  -.3273119019     1.1442104      -.286  .7748 .45762712
 PRDSEXF  .2911691851     1.1644035       .250  .8025 .65254237
 SCOTCHY -3.171250618     1.3707560     -2.314  .0207 .47457627
          Characteristics in numerator of Prob[Y = 2]
 Constant -6.865048363     4.3960383     -1.562  .1184
 MPT1ST   1.253675124     .61606924      2.035  .0419 3.8805085
 JOINDAR -.3707307105E-01 .16453889      -.225  .8217 9.7381356
 INMDAR  -1.218915042     3.7320722      -.327  .7440 .39016949
 CROP1ST -3.625809016     1.7243870     -2.103  .0355 .16101695
 HERDF    1.295935851     1.8909557       .685  .4931 .60847458
 MAIZTOT  2.493549199     3.0854374       .808  .4190 .40974576
 LANDPRB -.8473578493E-01 1.4541624      -.058  .9535 .34745763
 DARYHER  .9687871153     .87107156      1.112  .2661 2.6271186
 INMILK   2.637447677     2.3432903      1.126  .2604 1.1186441
 DELIVY  -.1750529694     1.4479976      -.121  .9038 .35593220
 MAIZLAB -1.058324838     .62586543     -1.691  .0908 2.3282203
 MPTAREA  6.810444209     3.8983540      1.747  .0806 .24800847
 RECORDY -.2397842661E-01 1.5158269      -.016  .9874 .37288136
 LFAYES   .9118740434     1.3807351       .660  .5090 .45762712
 PRDSEXF  1.027710740     1.5601296       .659  .5101 .65254237
 SCOTCHY -5.835100023     1.8212449     -3.204  .0014 .47457627
 Characteristics in numerator of Prob[Y = 3]
Constant  7.203084236      3.5990453          2.001   .0454
MPT1ST   -1.648033586      .67858009         -2.429   .0152  3.8805085
JOINDAR    .2091337319     .17325449          1.207   .2274  9.7381356
INMDAR   -8.174148672     4.4796542          -1.825   .0680   .39016949
CROP1ST  -4.494876451     1.6171290          -2.780   .0054   .16101695
HERDF     -.2184688574    1.7415935           -.125   .9002   .60847458
MAIZTOT   1.043376746     3.6933529            .283   .7776   .40974576
LANDPRB   1.649439636     1.5128929           1.090   .2756   .34745763
DARYHER   -.1702311613     .77617147          -.219   .8264  2.6271186
INMILK    3.531581479     2.3229747           1.520   .1284  1.1186441
DELIVY    -.2915135225    1.7076445           -.171   .8645   .35593220
MAIZLAB  -1.385159005      .69982640         -1.979   .0478  2.3282203
MPTAREA   8.729902363     4.1120940           2.123   .0338   .24800847
RECORDY   1.851212330     1.4021247           1.320   .1867   .37288136
LFAYES   -1.273829101     1.3853832           -.919   .3578   .45762712
PRDSEXF    .1791805031    1.3038534            .137   .8907   .65254237
SCOTCHY  -1.918175876     1.4994397          -1.279   .2008   .47457627
+-------------------------------------------+
| Partial derivatives of probabilities with |
| respect to the vector of characteristics. |
| They are computed at the means of the Xs. |
| Observations used for means are All Obs.  |
| A full set is given for the entire set of |
| outcomes, CC       = 0 to CC       =  3.  |
| Probabilities at the mean vector are      |
|  0= .013 1= .879 2= .051 3= .057          |
+---------+--------------+----------------+--------+---------+------
---+
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------
          Marginal effects on Prob[Y = 0]
Constant -.5562213057E-01 .58013005E-01    -.959   .3377
MPT1ST    .1662921313E-01 .17114888E-01     .972   .3312  3.8805085
JOINDAR  -.1186999726E-02 .20138611E-02    -.589   .5556  9.7381356
INMDAR    .1992836089E-01 .38277223E-01     .521   .6026   .39016949
CROP1ST   .5202035522E-01 .46445631E-01    1.120   .2627   .16101695
HERDF    -.2403668378E-01 .29163927E-01    -.824   .4098   .60847458
MAIZTOT  -.2238809174E-01 .42631186E-01    -.525   .5995   .40974576
LANDPRB  -.3086787503E-01 .28486768E-01   -1.084   .2785   .34745763
DARYHER  -.1077284117E-01 .13891744E-01    -.775   .4381  2.6271186
INMILK   -.2178284385E-01 .23329734E-01    -.934   .3505  1.1186441
DELIVY    .9977439322E-02 .19773250E-01     .505   .6138   .35593220
MAIZLAB   .1425104726E-01 .12741630E-01    1.118   .2634  2.3282203
MPTAREA  -.1317098589     .11907449       -1.106   .2687   .24800847
RECORDY  -.3163820886E-02 .16638865E-01    -.190   .8492   .37288136
LFAYES    .4220869131E-02 .15296927E-01     .276   .7826   .45762712
PRDSEXF  -.4270536425E-02 .15710455E-01    -.272   .7858   .65254237
SCOTCHY   .4284271726E-01 .38829404E-01    1.103   .2699   .47457627
           Marginal effects on Prob[Y = 1]
Constant  .4378209103     .31613840        1.385   .1661
MPT1ST   -.1194309296     .66267724E-01   -1.802   .0715  3.8805085
JOINDAR   .6191590781E-03 .10839467E-01     .057   .9544  9.7381356
INMDAR    .3504724127     .25769496        1.360   .1738   .39016949
CROP1ST  -.2912504155E-01 .10738609        -.271   .7862   .16101695
HERDF     .1643962509     .10181477        1.615   .1064   .60847458
MAIZTOT   .1639343665E-01 .22672654         .072   .9424   .40974576
LANDPRB   .1889782788     .91896698E-01    2.056   .0397   .34745763
DARYHER   .5817336786E-01 .56207261E-01    1.035   .3007  2.6271186
INMILK   -.1391546327     .13014659       -1.069   .2850  1.1186441
DELIVY   -.6469282065E-01 .82647615E-01    -.783   .4338   .35593220
```

```
 MAIZLAB    .4140232399E-02  .35443389E-01      .117     .9070  2.3282203
 MPTAREA    .3459010915      .20513879         1.686     .0918  .24800847
 RECORDY   -.7638257284E-01  .76629594E-01     -.997     .3189  .37288136
 LFAYES    -.1129919028E-01  .74082916E-01     -.153     .8788  .45762712
 PRDSEXF   -.2370398364E-01  .75258501E-01     -.315     .7528  .65254237
 SCOTCHY    .1799931359E-01  .96323470E-01      .187     .8518  .47457627
           Marginal effects on Prob[Y = 2]
 Constant  -.5577499784      .26482059        -2.106     .0352
 MPT1ST     .1262813370      .61389556E-01     2.057     .0397  3.8805085
 JOINDAR   -.6358479359E-02  .74292175E-02     -.856     .3921  9.7381356
 INMDAR     .1346276992E-01  .12472087          .108     .9140  .39016949
 CROP1ST    .1264843854E-01  .68962195E-01      .183     .8545  .16101695
 HERDF     -.2506706842E-01  .63438837E-01     -.395     .6927  .60847458
 MAIZTOT    .4183105870E-01  .11937318          .350     .7260  .40974576
 LANDPRB   -.1208008487      .70183373E-01    -1.721     .0852  .34745763
 DARYHER    .8421415852E-02  .33034862E-01      .255     .7988  2.6271186
 INMILK     .5140595599E-01  .86682105E-01      .593     .5532  1.1186441
 DELIVY     .2879002651E-01  .45227943E-01      .637     .5244  .35593220
 MAIZLAB    .1704129592E-03  .19130977E-01      .009     .9929  2.3282203
 MPTAREA   -.1520829567      .12360012        -1.230     .2185  .24800847
 RECORDY   -.1315637487E-01  .49092125E-01     -.268     .7887  .37288136
 LFAYES     .6213029150E-01  .48197674E-01     1.289     .1974  .45762712
 PRDSEXF    .3594903272E-01  .55159413E-01      .652     .5146  .65254237
 SCOTCHY   -.1339228067      .72057783E-01    -1.859     .0631  .47457627
           Marginal effects on Prob[Y = 3]
 Constant   .1755511987      .16070868         1.092     .2747
 MPT1ST    -.2347962057E-01  .23102437E-01    -1.016     .3095  3.8805085
 JOINDAR    .6926320007E-02  .74655137E-02      .928     .3535  9.7381356
 INMDAR    -.3838635435      .22265503        -1.724     .0847  .39016949
 CROP1ST   -.3554375221E-01  .64553081E-01     -.551     .5819  .16101695
 HERDF     -.1152924987      .76703992E-01    -1.503     .1328  .60847458
 MAIZTOT   -.3583640360E-01  .16515412         -.217     .8282  .40974576
 LANDPRB   -.3730955507E-01  .56672409E-01     -.658     .5103  .34745763
 DARYHER   -.5582194254E-01  .42981764E-01    -1.299     .1940  2.6271186
 INMILK     .1095315206      .93706321E-01     1.169     .2425  1.1186441
 DELIVY     .2592535481E-01  .64233460E-01      .404     .6865  .35593220
 MAIZLAB   -.1856169262E-01  .25999509E-01     -.714     .4753  2.3282203
 MPTAREA   -.6210827595E-01  .12864483         -.483     .6292  .24800847
 RECORDY    .9270276859E-01  .55060224E-01     1.684     .0922  .37288136
 LFAYES    -.5505197036E-01  .53337163E-01    -1.032     .3020  .45762712
 PRDSEXF   -.7974512655E-02  .47680932E-01     -.167     .8672  .65254237
 SCOTCHY    .7308077583E-01  .56368971E-01     1.296     .1948  .47457627
Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.
             Predicted
------  --------------------  +  -----
Actual       0     1     2     3  |  Total
------  --------------------  +  -----
  0         12     2     3     1  |     18
  1          1    62     2     2  |     67
  2          2     3    15     0  |     20
  3          0     4     0     9  |     13
------  --------------------  +  -----
Total       15    71    20    12  |    118
```

APPENDIX III:

Results of MNL Model D1 tested on dry season data

```
              +---------------------------------------------+
              | Multinomial Logit Model                     |
              | Maximum Likelihood Estimates                |
              | Dependent variable                    CC    |
              | Weighting variable                   ONE    |
              | Number of observations               118    |
              | Iterations completed                  13    |
              | Log likelihood function        -62.25004    |
              | Restricted log likelihood      -141.6107    |
              | Chi-squared                     158.7213    |
              | Degrees of freedom                    42    |
              | Significance level              .0000000    |
              +---------------------------------------------+
+---------+--------------+----------------+--------+---------+------
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z]| Mean of X|
+--------+-------------+----------------+--------+---------+---------
         Characteristics in numerator of Prob[Y = 1]
 Constant  11.49475388       14.931685          .770   .4414
 MPT1ST   -.9857302358       1.3019641         -.757   .4490  3.8805085
 JOINDAR  -1.092235761       1.1486371         -.951   .3417  9.7381356
 INMDAR    4.154354774       7.0185802          .592   .5539  .42288136
 CROP1ST  -16.53303734       13.317092        -1.241   .2144  .16101695
 HERDF     11.76604579       9.5846527         1.228   .2196  .60338983
 SCOTCHY  -13.19735086       10.938529        -1.207   .2276  .47457627
 MPTAREA   46.77936940       41.928515         1.116   .2646  .24038136
 INMILK   -1.981598754       5.7435667         -.345   .7301  1.1779661
 DELIVY    4.309550704       6.5100946          .662   .5080  .34745763
 MAIZTOT  -.7437810988       7.3178505         -.102   .9190  .40974576
 LANDPRB   .6729597983       2.6046252          .258   .7961  .34745763
 RECORDY   7.873190261       5.7405303         1.372   .1702  .37288136
 PRDSEXF  -4.197091374       5.1729812         -.811   .4172  .65254237
 DARYHER   4.861923263       3.6363146         1.337   .1812  2.6525424
         Characteristics in numerator of Prob[Y = 2]
 Constant  5.203030315       15.066880          .345   .7298
 MPT1ST    .3568891218       1.3219913          .270   .7872  3.8805085
 JOINDAR  -1.088699560       1.1507169         -.946   .3441  9.7381356
 INMDAR    4.919667039       6.9907980          .704   .4816  .42288136
 CROP1ST  -19.20625912       13.261015        -1.448   .1475  .16101695
 HERDF     12.39225592       9.6099974         1.290   .1972  .60338983
 SCOTCHY  -13.88248993       10.971144        -1.265   .2057  .47457627
 MPTAREA   41.83756611       41.939169          .998   .3185  .24038136
 INMILK   -.5879162304       5.7438144         -.102   .9185  1.1779661
 DELIVY    3.961967143       6.5151679          .608   .5431  .34745763
 MAIZTOT  -.4565858687E-02   7.5241853         -.001   .9995  .40974576
 LANDPRB   .5780694730       2.6132851          .221   .8249  .34745763
 RECORDY   7.730231520       5.7803450         1.337   .1811  .37288136
 PRDSEXF  -4.357752832       5.2146449         -.836   .4033  .65254237
 DARYHER   4.600204879       3.6355744         1.265   .2058  2.6525424
```

```
  Characteristics in numerator of Prob[Y = 3]
Constant  18.23871155      14.874709        1.226   .2201
MPT1ST   -1.913575865      1.3930667       -1.374   .1696  3.8805085
JOINDAR  -.6663439253      1.1770511        -.566   .5713  9.7381356
INMDAR   -4.224234083      8.0377079        -.526   .5992  .42288136
CROP1ST  -18.69024864      13.593128       -1.375   .1691  .16101695
HERDF     3.845358445      9.9409017         .387   .6989  .60338983
SCOTCHY  -11.90638872      10.947060       -1.088   .2768  .47457627
MPTAREA   45.99242346      41.878458        1.098   .2721  .24038136
INMILK    .9433611313      6.1266126         .154   .8776  1.1779661
DELIVY    6.927067299      6.7272448        1.030   .3031  .34745763
MAIZTOT  -3.477707316      7.6748938        -.453   .6505  .40974576
LANDPRB  -.9676847600      2.7626291        -.350   .7261  .34745763
RECORDY   7.900025014      5.7510936        1.374   .1695  .37288136
PRDSEXF  -4.987053063      5.2109938        -.957   .3386  .65254237
DARYHER   2.211871369      3.6108309         .613   .5402  2.6525424

+----------------------------------------------+
| Partial derivatives of probabilities with   |
| respect to the vector of characteristics.   |
| They are computed at the means of the Xs.   |
| Observations used for means are All Obs.    |
| A full set is given for the entire set of   |
| outcomes, CC       = 0 to CC       =  3.    |
| Probabilities at the mean vector are         |
|  0= .000 1= .792 2= .205 3= .002             |
+----------------------------------------------+
+---------+--------------+----------------+--------+---------+------
|Variable | Coefficient  | Standard Error |b/St.Er.|P[|Z|>z] | Mean of X|
+---------+--------------+----------------+--------+---------+----------
          Marginal effects on Prob[Y = 0]
Constant -.1124540464E-07  .19466012E-06    -.058   .9539
MPT1ST    .7838482294E-09  .12595006E-07     .062   .9504  3.8805085
JOINDAR   .1200039450E-08  .20567845E-07     .058   .9535  9.7381356
INMDAR   -.4722904398E-08  .79141884E-07    -.060   .9524  .42288136
CROP1ST   .1880290768E-07  .31976848E-06     .059   .9531  .16101695
HERDF    -.1306883144E-07  .22166573E-06    -.059   .9530  .60338983
SCOTCHY   .1467426055E-07  .25009210E-06     .059   .9532  .47457627
MPTAREA  -.5035936186E-07  .86236362E-06    -.058   .9534  .24038136
INMILK    .1858287865E-08  .31776556E-07     .058   .9534  1.1779661
DELIVY   -.4670602712E-08  .80954843E-07    -.058   .9540  .34745763
MAIZTOT   .6585436975E-09  .16763528E-07     .039   .9687  .40974576
LANDPRB  -.7148925769E-09  .11131986E-07    -.064   .9488  .34745763
RECORDY  -.8631709493E-08  .14568969E-06    -.059   .9528  .37288136
PRDSEXF   .4656948188E-08  .80614979E-07     .058   .9539  .65254237
DARYHER  -.5284292761E-08  .89330969E-07    -.059   .9528  2.6525424
          Marginal effects on Prob[Y = 1]
Constant  1.010858788      .40576940        2.491   .0127
MPT1ST   -.2166591208      .97023381E-01   -2.233   .0255  3.8805085
JOINDAR  -.1364339997E-02  .14626931E-01    -.093   .9257  9.7381356
INMDAR   -.1089533927      .26391462        -.413   .6797  .42288136
CROP1ST   .4387995175      .21891072        2.004   .0450  .16101695
HERDF    -.8717676771E-01  .11945687        -.730   .4655  .60338983
SCOTCHY   .1090464203      .12160389         .897   .3699  .47457627
MPTAREA   .8052475814      .45531526        1.769   .0770  .24038136
INMILK   -.2321037994      .14916234       -1.556   .1197  1.1779661
DELIVY    .5168459769E-01  .11203259         .461   .6446  .34745763
MAIZTOT  -.1151681806      .33259449        -.346   .7291  .40974576
LANDPRB   .1847410312E-01  .10942077         .169   .8659  .34745763
RECORDY   .2320266731E-01  .11208189         .207   .8360  .37288136
```

```
PRDSEXF    .2759553559E-01  .11858454          .233     .8160  .65254237
DARYHER    .4747928006E-01  .60051817E-01      .791     .4292  2.6525424
          Marginal effects on Prob[Y = 2]
Constant -1.029612411       .68584988        -1.501     .1333
MPT1ST     .2194682361      .12739823         1.723     .0849  3.8805085
JOINDAR    .3724345271E-03  .14598687E-01      .026     .9796  9.7381356
INMDAR     .1288679187      .28398003          .454     .6500  .42288136
CROP1ST   -.4350499364      .38938783        -1.117     .2639  .16101695
HERDF      .1059562526      .14285220          .742     .4583  .60338983
SCOTCHY   -.1123871061      .13256122         -.848     .3965  .47457627
MPTAREA   -.8057836729      .53801698        -1.498     .1342  .24038136
INMILK     .2259488650      .15903620         1.421     .1554  1.1779661
DELIVY    -.5795807577E-01  .10866982         -.533     .5938  .34745763
MAIZTOT    .1219012295      .34815951          .350     .7262  .40974576
LANDPRB   -.1469204165E-01  .10836760         -.136     .8922  .34745763
RECORDY   -.2333388452E-01  .11121267         -.210     .8338  .37288136
PRDSEXF   -.2582968497E-01  .11919154         -.217     .8284  .65254237
DARYHER   -.4142235412E-01  .59940118E-01     -.691     .4895  2.6525424
          Marginal effects on Prob[Y = 3]
Constant   .1875363473E-01  .43383868E-01      .432     .6655
MPT1ST    -.2809116159E-02  .65209485E-02     -.431     .6666  3.8805085
JOINDAR    .9919042696E-03  .22139780E-02      .448     .6541  9.7381356
INMDAR    -.1991452122E-01  .43476871E-01     -.458     .6469  .42288136
CROP1ST   -.3749599924E-02  .10509358E-01     -.357     .7213  .16101695
HERDF     -.1877947186E-01  .43835404E-01     -.428     .6684  .60338983
SCOTCHY    .3340671180E-02  .80830248E-02      .413     .6794  .47457627
MPTAREA    .5361418774E-03  .51899585E-02      .103     .9177  .24038136
INMILK     .6154932510E-02  .14986816E-01      .411     .6813  1.1779661
DELIVY     .6273482752E-02  .14849408E-01      .422     .6727  .34745763
MAIZTOT   -.6733049588E-02  .17777769E-01     -.379     .7049  .40974576
LANDPRB   -.3782060748E-02  .86911606E-02     -.435     .6634  .34745763
RECORDY    .1312258390E-03  .28229952E-02      .046     .9629  .37288136
PRDSEXF   -.1765855278E-02  .48831338E-02     -.362     .7176  .65254237
DARYHER   -.6056920656E-02  .13596894E-01     -.445     .6560  2.6525424

Frequencies of actual & predicted outcomes
Predicted outcome has maximum probability.

            Predicted
------  --------------------  +  -----
Actual      0    1    2    3  |  Total
------  --------------------  +  -----
  0        12    1    2    0  |     15
  1         1   51    4    2  |     58
  2         0   18   14    1  |     33
  3         0    2    0   10  |     12
------  --------------------  +  -----
Total      13   72   20   13  |    118
```